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MCS-80/85™ FAMILY USER'S MANUAL

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MCS-80/85™ FAMILY USER'S MANUAL

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MCS-85™ User's Manual
Table of Contents

CHAPTER 1
Part 1: Introduction to the Functions of a Computer 1-1
Part 2: Introduction to MCS-85™ 1-6

CHAPTER 2
Functional Description 2-1

CHAPTER 3
System Operation and Interfacing 3-1

CHAPTER 4
The 8080 Central Processor Unit 4-1

CHAPTER 5
The Instruction Set 5-1
Instruction Set Index 5-19

CHAPTER 6

DEVICE SPECIFICATIONS

MCS-85
8085A/8085A-2 8-Bit Microprocessor 6-1
8155/8156/8155-2/8156-2 RAM/IO/Counter-Timer 6-17
8185/8185-2 RAM 6-32
8355/8355-2 ROM/IO 6-37
8755A/8755A-2 EPROM/IO 6-45

MCS-80
8080A/8080A-1/8080A-2 8-Bit Microprocessor 6-56
8224 Clock Generator and Driver 6-64
8228/8238 System Controller and Bus Driver 6-68
8801 Clock Generator Crystal 6-72

System Support Components
8205 High-Speed 1 Out of 8 Binary Decoder 6-74
8212 8-Bit Input/Output Port 6-80
8218/8219 Bi-polar Microcomputer Bus Controllers 6-90
8237/8237-2 High Performance Programmable DMA Controller 6-101
8257/8257-5 Programmable DMA Controller 6-115
8259A/8259A-2/8259A-8 Programmable Interrupt Controller 6-132
8282/8283 Octal Latch 6-150
8286/8287 Octal Bus Transceiver 6-154

Table of Contents (Continued)

Peripherals*

8041A/8641A/8741A Universal Peripheral Interface 6-158
8202 Dynamic RAM Controller 6-159
8251A Programmable Communication Interface 6-160
8253/8253-5 Programmable Interval Timer 6-161
8255A/8255A-5 Programmable Peripheral Interface 6-162
8271 Programmable Floppy Disk Controller 6-163
8272 Single/Double Density Floppy Disk Controller 6-164
8273 Programmable HDLC/SDLC Protocol Controller 6-165
8275 Programmable CRT Controller 6-166
8279/8279-5 Programmable Keyboard/Display Interface 6-167
8291 GPIB Talker/Listener 6-168
8292 GPIB Controller 6-169
8293 GPIB Transceiver 6-170
8294 Data Encryption Unit 6-171
8295 Dot Matrix Printer Controller 6-172

Static RAMs

2114A 1024 × 4 Bit Static RAM 6-173
2141 4096 × 1 Bit Static RAM 6-174
2142 1024 × 4 Bit Static RAM 6-175
2148 1024 × 4 Bit Static RAM 6-176

ROMs/EPROMs

2716 16K (2K × 8) UV Erasable PROM 6-177
2732 32K (4K × 8) UV Erasable PROM 6-178
2758 8K (1K × 8) UV Erasable Low Power PROM 6-182
3604A, 3624A 4K (512 × 8) High-Speed PROM 6-183
3605A, 3625A 4K (1K × 4) PROM 6-184
3628 8K (1K × 8) Bipolar PROM 6-187
3636 16K (2K × 8) Bipolar PROM 6-190

CHAPTER 7

DEVELOPMENT AIDS

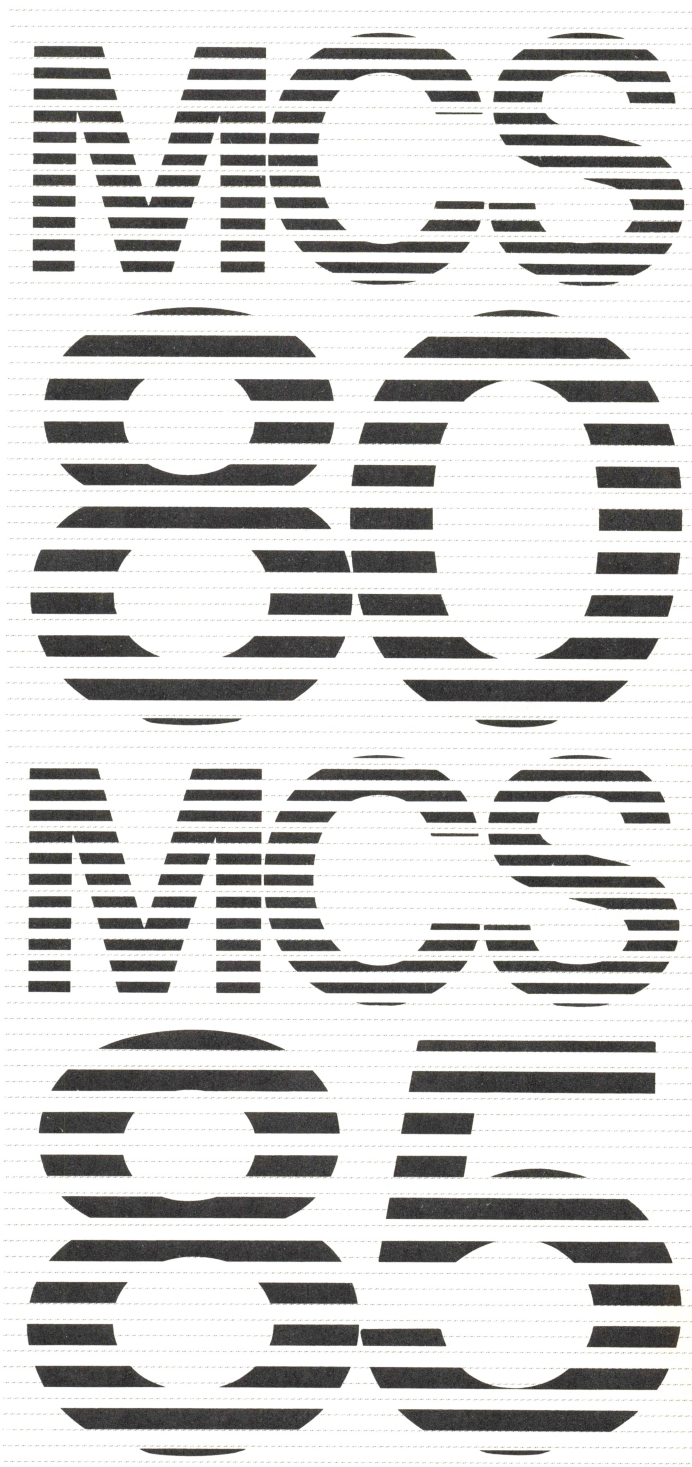
ICE-80™ MCS-80™ In-Circuit Emulator 7-1
UPP-103 Universal PROM Programmer 7-7
Intellec® Microcomputer Development System Model 220 7-9
Intellec® Microcomputer Development System Model 230 7-13
ISIS-II Diskette Operating System 7-17
PL/M-80 High Level Programming Language Intellec® Resident Computer 7-20
ICE-85™ MCS-85™ In-Circuit Emulator 7-23
SDK-85 MCS-85™ System Design Kit 7-27
Fortran-80 8080/8085 ANS Fortran 77 Intellec® Resident Compiler 7-33
Basic-80 Extended ANS 1978 Basic Intellec® Resident Interpreter 7-37
ICIS-Cobol™ Software Package 7-40

APPENDIX

Applications of MCS-85™ A1-1

*This section contains partial data sheets. For complete details, refer to the Intel Peripheral Design Handbook.

Chapter 1
Introduction



CHAPTER 1
PART 1: INTRODUCTION TO THE FUNCTIONS OF A COMPUTER

This chapter introduces certain basic computer concepts. It provides background information and definitions which will be useful in later chapters of this manual. Those already familiar with computers may skip this material, at their option.

A TYPICAL COMPUTER SYSTEM

A typical digital computer consists of:

a) A central processor unit (CPU)
b) A memory
c) Input/output (I/O) ports

The memory serves as a place to store **Instructions**, the coded pieces of information that direct the activities of the CPU, and **Data**, the coded pieces of information that are processed by the CPU. A group of logically related instructions stored in memory is referred to as a **Program**. The CPU "reads" each instruction from memory in a logically determined sequence, and uses it to initiate processing actions. If the program sequence is coherent and logical, processing the program will produce intelligible and useful results.

The memory is also used to store the data to be manipulated, as well as the instructions that direct that manipulation. The program must be organized such that the CPU does not read a non-instruction word when it expects to see an instruction. The CPU can rapidly access any data stored in memory; but often the memory is not large enough to store the entire data bank required for a particular application. The problem can be resolved by providing the computer with one or more **Input Ports**. The CPU can address these ports and input the data contained there. The addition of input ports enables the computer to receive information from external equipment (such as a paper tape reader or floppy disk) at high rates of speed and in large volumes.

A computer also requires one or more **Output Ports** that permit the CPU to communicate the result of its processing to the outside world. The output may go to a display, for use by a human operator, to a peripheral device that produces "hard-copy," such as a line-printer, to a peripheral storage device, such as a floppy disk unit, or the output may constitute process control signals that direct the operations of another system, such as an automated assembly line. Like input ports, output ports are addressable. The input and output ports together permit the processor to communicate with the outside world.

The CPU unifies the system. It controls the functions performed by the other components. The CPU must be able to fetch instructions from memory, decode their binary contents and execute them. It must also be able to reference memory and I/O ports as necessary in the execution of instructions. In addition, the CPU should be able to recognize and respond to certain external control signals, such as INTERRUPT and WAIT requests. The functional units within a CPU that enable it to perform these functions are described below.

THE ARCHITECTURE OF A CPU

A typical central processor unit (CPU) consists of the following interconnected functional units:

- Registers
- Arithmetic/Logic Unit (ALU)
- Control Circuitry

Registers are temporary storage units within the CPU. Some registers, such as the program counter and instruction register, have dedicated uses. Other registers, such as the accumulator, are for more general purpose use.

Accumulator:

The accumulator usually stores one of the operands to be manipulated by the ALU. A typical instruction might direct the ALU to add the contents of some other register to the contents of the accumulator and store the result in the accumulator itself. In general, the accumulator is both a source (operand) and a destination (result) register.

Often a CPU will include a number of additional general purpose registers that can be used to store operands or intermediate data. The availability of general purpose

registers eliminates the need to "shuffle" intermediate results back and forth between memory and the accumulator, thus improving processing speed and efficiency.

Program Counter (Jumps, Subroutines and the Stack):

The instructions that make up a program are stored in the system's memory. The central processor references the contents of memory, in order to determine what action is appropriate. This means that the processor must know which location contains the next instruction.

Each of the locations in memory is numbered, to distinguish it from all other locations in memory. The number which identifies a memory location is called its **Address**.

The processor maintains a counter which contains the address of the next program instruction. This register is called the **Program Counter**. The processor updates the program counter by adding "1" to the counter each time it fetches an instruction, so that the program counter is always current (pointing to the next instruction).

The programmer therefore stores his instructions in numerically adjacent addresses, so that the lower addresses contain the first instructions to be executed and the higher addresses contain later instructions. The only time the programmer may violate this sequential rule is when an instruction in one section of memory is a **Jump** instruction to another section of memory.

A jump instruction contains the address of the instruction which is to follow it. The next instruction may be stored in any memory location, as long as the programmed jump specifies the correct address. During the execution of a jump instruction, the processor replaces the contents of its program counter with the address embodied in the Jump. Thus, the logical continuity of the program is maintained.

A special kind of program jump occurs when the stored program "**Calls**" a subroutine. In this kind of jump, the processor is required to "remember" the contents of the program counter at the time that the jump occurs. This enables the processor to resume execution of the main program when it is finished with the last instruction of the subroutine.

A **Subroutine** is a program within a program. Usually it is a general-purpose set of instructions that must be executed repeatedly in the course of a main program. Routines which calculate the square, the sine, or the logarithm of a program variable are good examples of functions often written as subroutines. Other examples might be programs designed for inputting or outputting data to a particular peripheral device.

The processor has a special way of handling subroutines, in order to insure an orderly return to the main program. When the processor receives a Call instruction, it increments the Program Counter and stores the counter's contents in a reserved memory area known as the **Stack**. The Stack thus saves the address of the instruction to be executed after the subroutine is completed. Then the processor loads the address specified in the Call into its Program Counter. The next instruction fetched will therefore be the first step of the subroutine.

The last instruction in any subroutine is a **Return**. Such an instruction need specify no address. When the processor fetches a Return instruction, it simply replaces the current contents of the Program Counter with the address on the top of the stack. This causes the processor to resume execution of the calling program at the point immediately following the original Call Instruction.

Subroutines are often **Nested**; that is, one subroutine will sometimes call a second subroutine. The second may call a third, and so on. This is perfectly acceptable, as long as the processor has enough capacity to store the necessary return addresses, and the logical provision for doing so. In other words, the maximum depth of nesting is determined by the depth of the stack itself. If the stack has space for storing three return addresses, then three levels of subroutines may be accommodated.

Processors have different ways of maintaining stacks. Some have facilities for the storage of return addresses built into the processor itself. Other processors use a reserved area of external memory as the stack and simply maintain a **Pointer** register which contains the address of the most recent stack entry. The external stack allows virtually unlimited subroutine nesting. In addition, if the processor provides instructions that cause the contents of the accumulator and other general purpose registers to be "pushed" onto the stack or "popped" off the stack via the address stored in the stack pointer, multi-level interrupt processing (described later in this chapter) is possible. The status of the processor (i.e., the contents of all the registers) can be saved in the stack when an interrupt is accepted and then restored after the interrupt has been serviced. This ability to save the processor's status at any given time is possible even if an interrupt service routine, itself, is interrupted.

Instruction Register and Decoder:

Every computer has a **Word Length** that is characteristic of that machine. A computer's word length is usually determined by the size of its internal storage elements and interconnecting paths (referred to as **Busses**); for example, a computer whose registers and busses can store and transfer 8 bits of information has a characteristic word length of 8-bits and is referred to as an 8-bit parallel processor. An eight-bit parallel processor generally finds it most efficient to deal with eight-bit binary fields, and the memory associated with such a processor is therefore organized to store eight bits in each addressable memory location. Data and instructions are stored in memory as eight-bit binary numbers, or as numbers that are integral multiples of eight bits: 16 bits, 24 bits, and so on. This characteristic eight-bit field is often referred to as a **Byte**.

Each operation that the processor can perform is identified by a unique byte of data known as an **Instruction**

Code or **Operation Code**. An eight-bit word used as an instruction code can distinguish between 256 alternative actions, more than adequate for most processors.

The processor fetches an instruction in two distinct operations. First, the processor transmits the address in its Program Counter to the memory. Then the memory returns the addressed byte to the processor. The CPU stores this instruction byte in a register known as the **Instruction Register**, and uses it to direct activities during the remainder of the instruction execution.

The mechanism by which the processor translates an instruction code into specific processing actions requires more elaboration than we can here afford. The concept, however, should be intuitively clear to any logic designer. The eight bits stored in the instruction register can be decoded and used to selectively activate one of a number of output lines, in this case up to 256 lines. Each line represents a set of activities associated with execution of a particular instruction code. The enabled line can be combined with selected timing pulses, to develop electrical signals that can then be used to initiate specific actions. This translation of code into action is performed by the **Instruction Decoder** and by the associated control circuitry.

An eight-bit instruction code is often sufficient to specify a particular processing action. There are times, however, when execution of the instruction requires more information than eight bits can convey.

One example of this is when the instruction references a memory location. The basic instruction code identifies the operation to be performed, but cannot specify the object address as well. In a case like this, a two- or three-byte instruction must be used. Successive instruction bytes are stored in sequentially adjacent memory locations, and the processor performs two or three fetches in succession to obtain the full instruction. The first byte retrieved from memory is placed in the processor's instruction register, and subsequent bytes are placed in temporary storage; the processor then proceeds with the execution phase. Such an instruction is referred to as **Variable Length**.

Address Register(s):

A CPU may use a register or register-pair to hold the address of a memory location that is to be accessed for data. If the address register is **Programmable**, (i.e., if there are instructions that allow the programmer to alter the contents of the register) the program can "build" an address in the address register prior to executing a **Memory Reference** instruction (i.e., an instruction that reads data from memory, writes data to memory or operates on data stored in memory).

Arithmetic/Logic Unit (ALU):

All processors contain an arithmetic/logic unit, which is often referred to simply as the **ALU**. The ALU, as its name implies, is that portion of the CPU hardware which performs the arithmetic and logical operations on the binary data.

The ALU must contain an **Adder** which is capable of combining the contents of two registers in accordance with the logic of binary arithmetic. This provision permits the processor to perform arithmetic manipulations on the data it obtains from memory and from its other inputs.

Using only the basic adder a capable programmer can write routines which will subtract, multiply and divide, giving the machine complete arithmetic capabilities. In practice, however, most ALUs provide other built-in functions, including hardware subtraction, boolean logic operations, and shift capabilities.

The ALU contains **Flag Bits** which specify certain conditions that arise in the course of arithmetic and logical manipulations. Flags typically include **Carry, Zero, Sign,** and **Parity**. It is possible to program jumps which are conditionally dependent on the status of one or more flags. Thus, for example, the program may be designed to jump to a special routine if the carry bit is set following an addition instruction.

Control Circuitry:

The control circuitry is the primary functional unit within a CPU. Using clock inputs, the control circuitry maintains the proper sequence of events required for any processing task. After an instruction is fetched and decoded, the control circuitry issues the appropriate signals (to units both internal and external to the CPU) for initiating the proper processing action. Often the control circuitry will be capable of responding to external signals, such as an interrupt or wait request. An **Interrupt** request will cause the control circuitry to temporarily interrupt main program execution, jump to a special routine to service the interrupting device, then automatically return to the main program. A **Wait** request is often issued by a memory or I/O element that operates slower than the CPU. The control circuitry will idle the CPU until the memory or I/O port is ready with the data.

COMPUTER OPERATIONS

There are certain operations that are basic to almost any computer. A sound understanding of these basic operations is a necessary prerequisite to examining the specific operations of a particular computer.

Timing:

The activities of the central processor are cyclical. The processor fetches an instruction, performs the operations required, fetches the next instruction, and so on. This orderly sequence of events requires precise timing, and the CPU therefore requires a free running oscillator clock which furnishes the reference for all processor actions. The combined fetch and execution of a single instruction is referred to as an **Instruction Cycle**. The portion of a cycle identified

with a clearly defined activity is called a **State**. And the interval between pulses of the timing oscillator is referred to as a **Clock Period**. As a general rule, one or more clock periods are necessary for the completion of a state, and there are several states in a cycle.

Instruction Fetch:

The first state(s) of any instruction cycle will be dedicated to fetching the next instruction. The CPU issues a read signal and the contents of the program counter are sent to memory, which responds by returning the next instruction word. The first byte of the instruction is placed in the instruction register. If the instruction consists of more than one byte, additional states are required to fetch each byte of the instruction. When the entire instruction is present in the CPU, the program counter is incremented (in preparation for the next instruction fetch) and the instruction is decoded. The operation specified in the instruction will be executed in the remaining states of the instruction cycle. The instruction may call for a memory read or write, an input or output and/or an internal CPU operation, such as a register-to-register transfer or an add-registers operation.

Memory Read:

An instruction **fetch** is merely a special memory read operation that brings the instruction to the CPU's instruction register. The instruction fetched may then call for data to be read from memory into the CPU. The CPU again issues a read signal and sends the proper memory address; memory responds by returning the requested word. The data received is placed in the accumulator or one of the other general purpose registers (not the instruction register).

Memory Write:

A memory write operation is similar to a read except for the direction of data flow. The CPU issues a write signal, sends the proper memory address, then sends the data word to be written into the addressed memory location.

Wait (memory synchronization):

As previously stated, the activities of the processor are timed by a master clock oscillator. The clock period determines the timing of all processing activity.

The speed of the processing cycle, however, is limited by the memory's **Access Time**. Once the processor has sent a read address to memory, it cannot proceed until the memory has had time to respond. Most memories are capable of responding much faster than the processing cycle requires. A few, however, cannot supply the addressed byte within the minimum time established by the processor's clock.

Therefore a processor should contain a synchronization provision, which permits the memory to request a **Wait state**. When the memory receives a read or write enable signal, it places a request signal on the processor's READY line, causing the CPU to idle temporarily. After the memory has had time to respond, it frees the processor's READY line, and the instruction cycle proceeds.

Input/Output:

Input and Output operations are similar to memory read and write operations with the exception that a peripheral I/O device is addressed instead of a memory location. The CPU issues the appropriate input or output control signal, sends the proper device address and either receives the data being input or sends the data to be output.

Data can be input/output in either parallel or serial form. All data within a digital computer is represented in binary coded form. A binary data word consists of a group of bits; each bit is either a one or a zero. **Parallel** I/O consists of transferring all bits in the word at the same time, one bit per line. **Serial** I/O consists of transferring one bit at a time on a single line. Naturally serial I/O is much slower, but it requires considerably less hardware than does parallel I/O.

Interrupts:

Interrupt provisions are included on many central processors, as a means of improving the processor's efficiency. Consider the case of a computer that is processing a large volume of data, portions of which are to be output to a printer. The CPU can output a byte of data within a single machine cycle but it may take the printer the equivalent of many machine cycles to actually print the character specified by the data byte. The CPU could then remain idle waiting until the printer can accept the next data byte. If an interrupt capability is implemented on the computer, the CPU can output a data byte then return to data processing. When the printer is ready to accept the next data byte, it can request an interrupt. When the CPU acknowledges the interrupt, it suspends main program execution and automatically branches to a routine that will output the next data byte. After the byte is output, the CPU continues with main program execution. Note that this is, in principle, quite similar to a subroutine call, except that the jump is initiated externally rather than by the program.

More complex interrupt structures are possible, in which several interrupting devices share the same processor but have different priority levels. Interruptive processing is an important feature that enables maximum untilization of a processor's capacity for high system throughput.

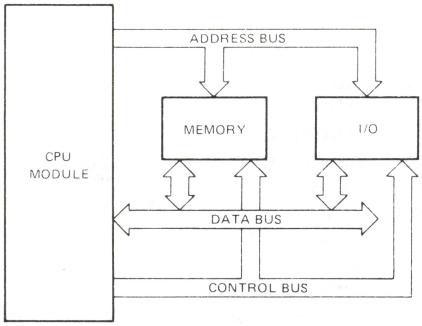
Hold:

Another important feature that improves the throughput of a processor is the **Hold**. The hold provision enables **Direct Memory Access** (DMA) operations.

In ordinary input and output operations, the processor itself supervises the entire data transfer. Information to be placed in memory is transferred from the input device to the processor, and then from the processor to the designated memory location. In similar fashion, information that goes

from memory to output devices goes by way of the processor.

Some peripheral devices, however, are capable of transferring information to and from memory much faster than the processor itself can accomplish the transfer. If any appreciable quantity of data must be transferred to or from such a device, then **system throughput** will be increased by having the device accomplish the transfer directly. The processor must temporarily suspend its operation during such a transfer, to prevent conflicts that would arise if processor and peripheral device attempted to access memory simultaneously. It is for this reason that a **hold** provision is included on some processors.

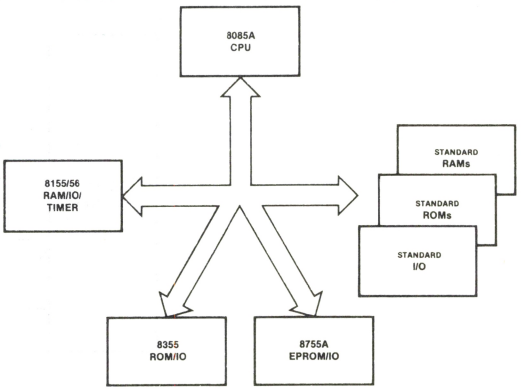


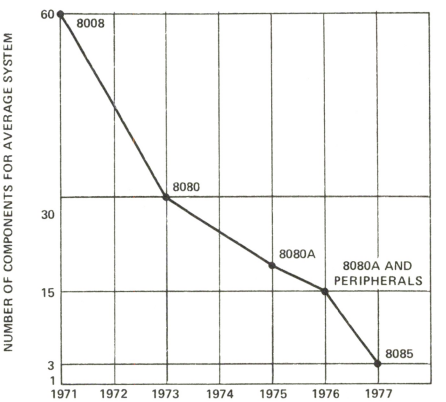
PART 2: INTRODUCTION TO MCS-85™

THE MCS-85™ MICROCOMPUTER SYSTEM

The basic philosophy behind the MCS-85 microcomputer system is one of logical, evolutionary advance in technology without the waste of discarding existing investments in hardware and software. The MCS-85 provides the existing 8080 user with an increase in performance, a decrease in the component count, operation from a single 5-Volt power supply, and still preserves 100% of his existing software investment. For the new microcomputer user, the MCS-85 represents the refinement of the most popular microcomputer in the industry, the Intel 8080, along with a wealth of supporting software, documentation and peripheral components to speed the cycle from prototype to production. The same development tools that Intel has produced to support the 8080 microcomputer system can be used for the MCS-85, and additional add-on features are available to optimize system development for MCS-85.

This section of the MCS-80/85 User's Manual will briefly detail the basic differences between the MCS-85 and MCS-80 families. It will illustrate both the hardware and software compatibilities and also reveal some of the engineering trade-offs that were met during the design of the MCS-85. More detailed discussion of the MCS-85 bus operation and component specifications are available in Chapters: 2, 3, 4, and 5. The information provided in Chapter 1 will be helpful in understanding the basic concepts and philosophies behind the MCS-85.



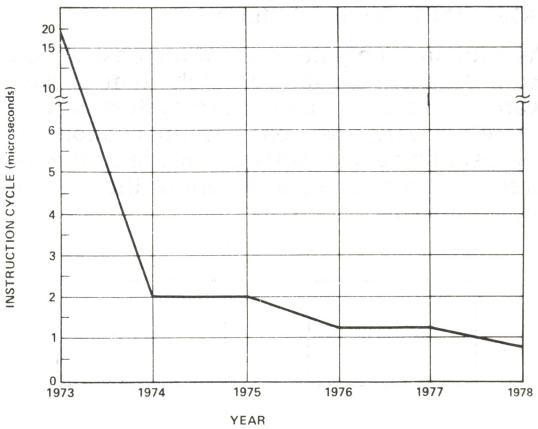


8-BIT SMALL SYSTEM COMPONENT COUNT 1971 – 1977

EVOLUTION

In December 1971, Intel introduced the first general purpose, 8-bit microprocessor, the 8008. It was implemented in P-channel MOS technology and was packaged in a single 18 pin, dual in-line package (DIP). The 8008 used standard semiconductor ROM and RAM and, for the most part, TTL components for I/O and general interface. It immediately found applications in byte-oriented end products such as terminals and computer peripherals where its instruction execution (20 micro-seconds), general

purpose organization and instruction set matched the requirements of these products. Recognizing that hardware was but a small part in the overall system picture, Intel developed both hardware and software tools for the design engineer so that the transition from prototype to production would be as simple and fast as possible. The commitment of providing a total systems approach with the 8008 microcomputer system was actually the basis for the sophisticated, comprehensive development tools that Intel has available today.

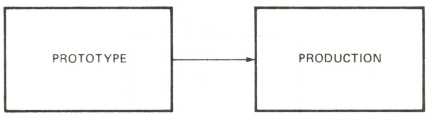


THE 8080A MICROPROCESSOR

With the advent of high-production N-channel RAM memories and 40 pin DIP packaging, Intel designed the 8080A microprocessor. It was designed to be software compatible with the 8008 so that the existing users of the 8008 could preserve their investment in software and at the same time provide dramatically increased performance (2 micro-second instruction execution), while reducing the amount of components necessary to implement a system. Additions were made to the basic instruction set to take advantage of this increased performance and large system-type features were included on-chip such as DMA, 16-bit addressing and external stack memory so that the total spectrum of application could be significantly increased. The 8080 was first sampled in December 1973. Since that time it has become the standard of the industry and is accepted as the primary building block for more microcomputer based applications than all other microcomputer systems combined.

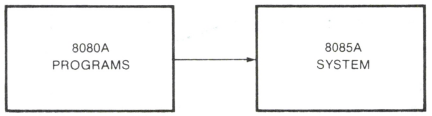
A TOTAL SYSTEMS COMMITMENT

The Intel® 8080A Microcomputer System encompasses a total systems commitment to the user to fully support his needs both in developing prototype systems and reliable, high volume production. From complex MOS/LSI peripheral components to resident high level systems language (PL/M) the Intel® 8080 Microcomputer System provides the most comprehensive, effective solution to today's system problems.



SOFTWARE COMPATIBILITY

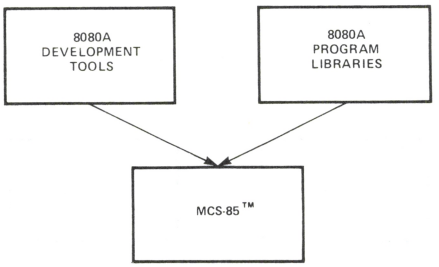
As with any computer system the cost of software development far outweighs that of hardware. A microcomputer-based system is traditionally a very cost-sensitive application and the development of software is one of the key areas where success or failure of the cost objectives is vital.



The 8085A CPU is 100% software compatible with the Intel® 8080A CPU. The compatibility is at the object or "machine code" level so that existing programs written for 8080A execution will run on the 8085A as is. The value of this becomes even more evident to the user who has mask programmed ROMs and wishes to update his system without the need for new masks.

PROGRAMMER TRAINING

A cost which is often forgotten is that of programmer training. A new, or modified instruction set, would require programmers to relearn another set of mnemonics and greatly affect the productivity during development. The 100% compatibility of the 8085A CPU assures that no re-training effort will be required.



For the new microcomputer user, the software compatibility between the 8085A and the 8080A means that all of the software development tools that are available for the 8080A and all software libraries for 8080A will operate with the new design and thus save immeasurable cost in development and debug.

The 8085A CPU does however add two instructions to initialize and maintain hardware features of the 8085A. Two of the unused opcodes of the 8080A instruction set were designated for the addition so that 100% compatibility could be maintained.

HARDWARE COMPATIBILITY

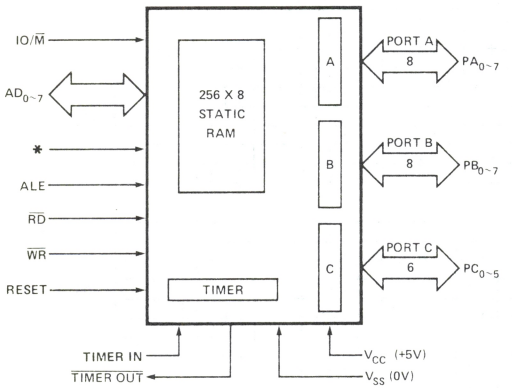
The integration of auxiliary 8080A functions, such as clock generation, system control and interrupt prioritization, dramatically reduces the amount of components necessary for most systems. In addition, the MCS-85 operates off a single +5 Volt power supply to further simplify hardware development and debug. A close examination of the AC/DC specifications of the MCS-85 systems components shows that each is specified to supply a minimum of 400μA of source current and a full TTL load of sink current so that a very substantial system can be constructed without the need for extra TTL buffers or drivers. Input and output voltage levels are also specified so that a minimum of 350mV noise margin is provided for reliable, high-performance operation.

PC BOARD CONSIDERATIONS

The 8085A CPU and the 8080A are not pin-compatible due to the reduction in power supplies and the addition of integrated auxiliary features. However, the pinouts of the MCS-85 system components were carefully assigned to minimize PC board area and thus yield a smooth, efficient layout. For new designs this incompatibility of pinouts presents no problems and for upgrades of existing designs the reduction of components and board area will far offset the incompatibility.

MCS-85™ SPECIAL PERIPHERAL COMPONENTS

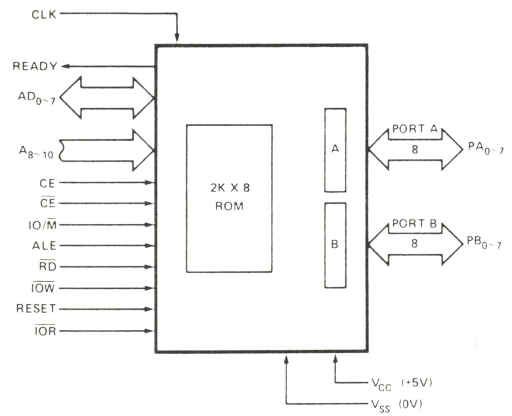
The MCS-85 was designed to minimize the amount of components required for most systems. Intel designed several new peripheral components that combine memory, I/O and timer functions to fulfill this requirement. These new peripheral devices directly interface to the multiplexed MCS-85 bus structure and provide new levels in system integration for today's designer.



*: 8155 = $\overline{CE}$, 8156 = CE

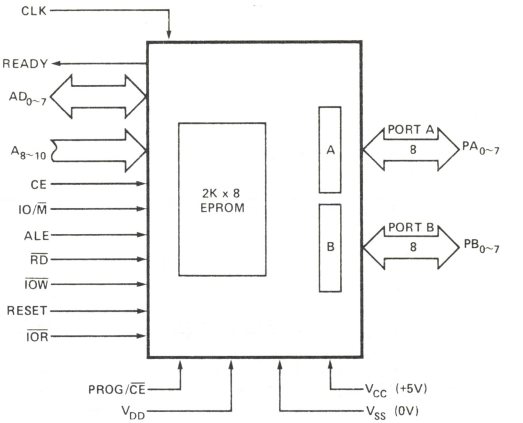
8155/8156 RAM, I/O and Timer

- 256 bytes RAM
- Two 8-bit ports
- One 6-bit port (programmable)
- One 14-bit programmable interval timer
- Single +5 Volt supply operation
- 40 pin DIP plastic or cerdip package



8355 ROM and I/O

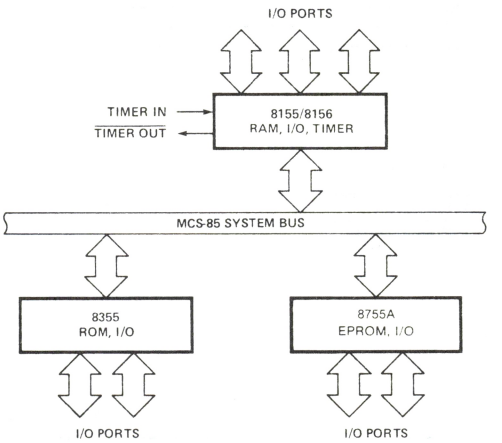
- 2K bytes ROM
- Two 8-bit ports (direction programmable)
- Single +5 Volt supply operation
- 40 pin DIP plastic or cerdip package



8755A EPROM and I/O

- Socket compatible with 8355
- 2K bytes EPROM
- Two 8-bit ports (direction programmable)
- Single +5 Volt supply read operation
- U.V. Erasable
- 40 pin DIP package

One of the most important advances made with the MCS-85 is the socket-compatibility of the 8355 and 8755A components. This allows the systems designer to develop and debug in erasable PROM and then, when satisfied, switch over to mask-programmed ROM 8355 with no performance degradation or board relayout. It also allows quick prototype production for market impact without going to a compromise solution.



SYSTEM EXPANSION

Each of these peripheral components has features that allow a small to medium system to be constructed without the addition of buffers and decoders to maintain the lowest possible component count.

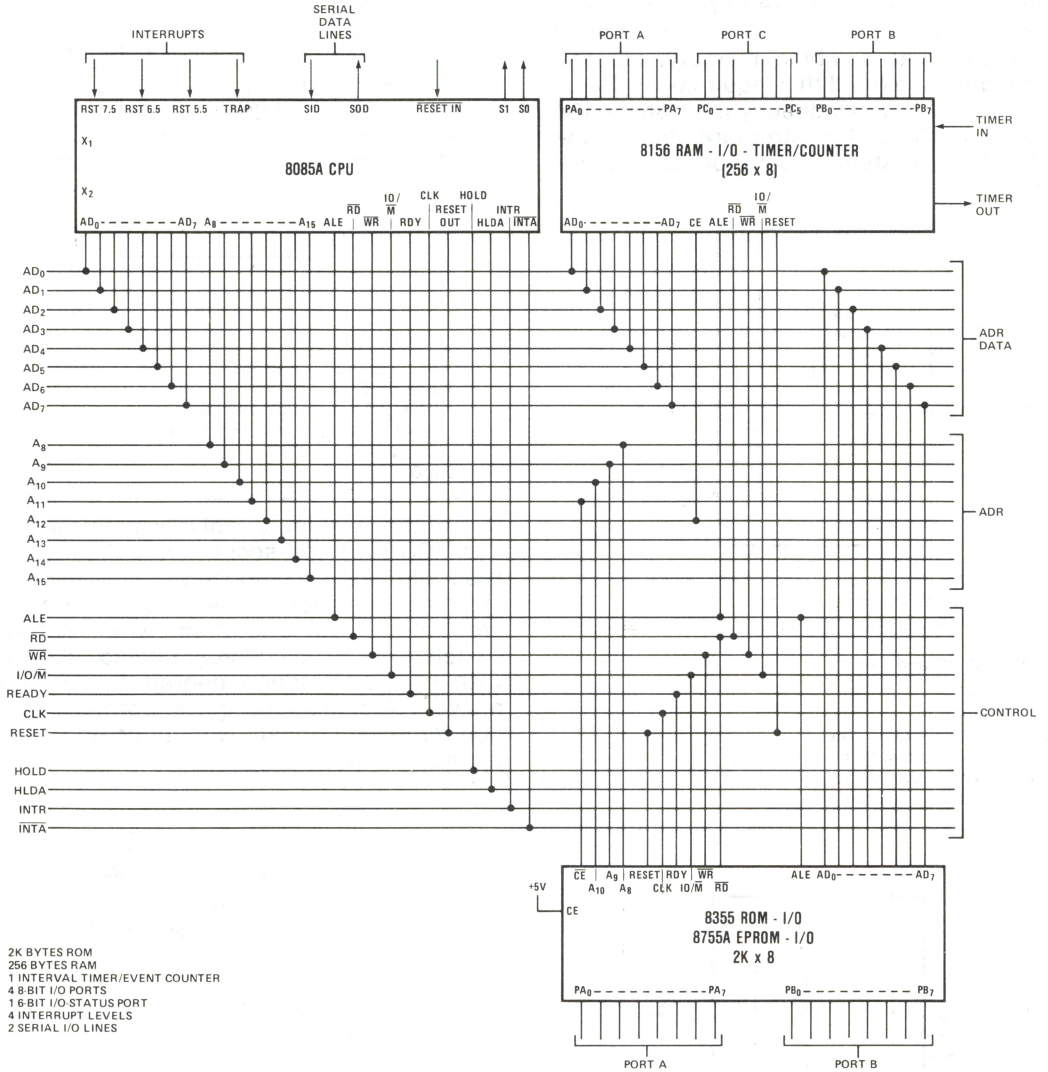
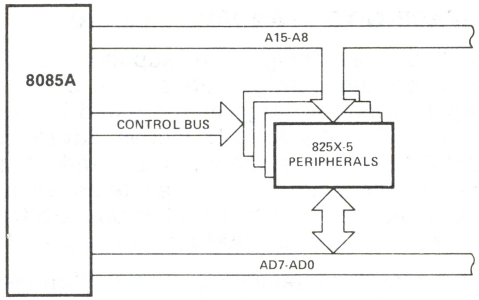
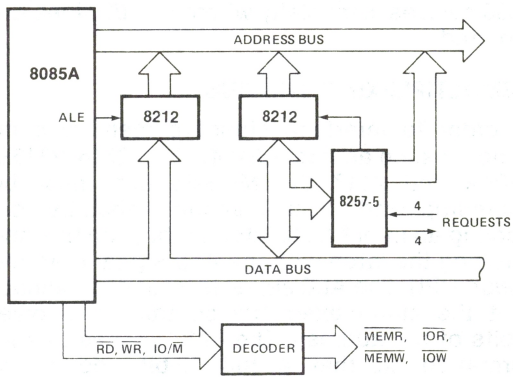


Figure 1-1. MCS-85™ Basic System

INTERFACING TO MCS-80/85™ PROGRAMMABLE PERIPHERAL COMPONENTS

The MCS-85 shares with the MCS-80 a wide range of peripheral components that solve system problems and provide the designer with a great deal of flexibility in his I/O, Interrupt and DMA structures. The MCS-85 is directly compatible with these peripherals, and, with the exception of the 8257-5 DMA controller, needs no additional circuitry for their interface in a minimum system. The 8257-5 DMA controller uses an 8212 latch and some gating to support the multiplexed bus of MCS-85.



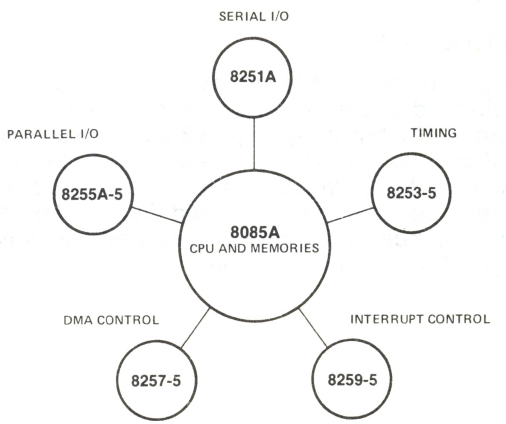


PROGRAMMABLE PERIPHERALS

The list of programmable peripherals for use with the 8085A includes:

8251A	Programmable Communications Interface
8253-5	Programmable Interval Timer
8255A-5	Programmable Peripheral Interface
8257-5	Programmable DMA Controller
8259-5	Programmable Interrupt Controller
8271	Diskette Controller
8273	Synchronous Data Link Controller
8275	CRT Controller
8278	Keyboard/Display Controller
8279	Keyboard/Display Controller

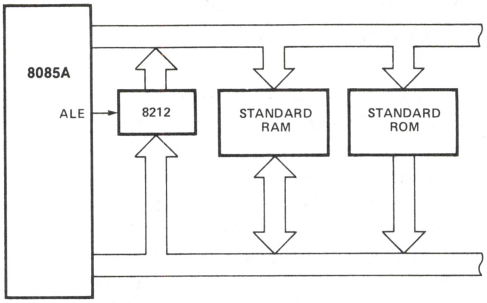
The MCS-80/85 peripheral compatibility assures the designer that all new peripheral components from Intel will interface to the MCS-85 bus structure to further expand the application spectrum of MCS-85.



INTERFACING TO STANDARD MEMORY

The MCS-85 was designed to support the full range of system configurations from small 3 chip applications to large memory and I/O applications. The 8085A CPU issues advanced READ/WRITE status signals (S0, S1, and IO/$\overline{M}$) so that, in the case of large systems, these signals could be used to simplify bus arbitration logic and dynamic RAM refresh circuitry.

In large, memory-intensive systems, standard memory devices may provide a more cost-effective solution than do the special 8155 and 8355 devices, especially where few I/O lines are required.



DEMULTIPLEXING THE BUS

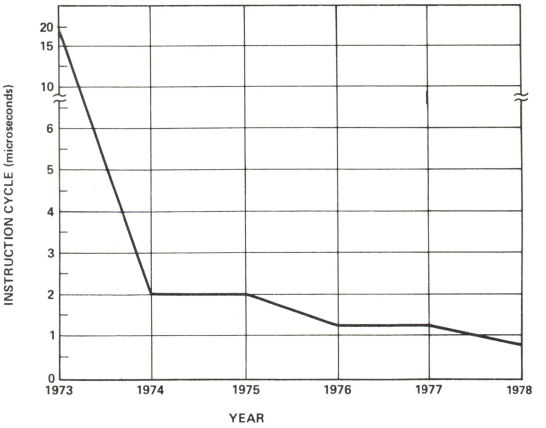
In order to interface standard memory components such as Intel® 2114, 2142, 2716, 2316E, 2104A and 2117 the MCS-85 bus must be "demultiplexed". This is accomplished by connecting an Intel® 8212 latch to the data bus and strobing the latch with the ALE signal from the 8085A CPU. The ALE signal is issued to indicate that the multiplexed bus contains the lower 8-bits of the address. The 8212 latches this information so that a full 16-bit address is available to interface standard memory components.

USE OF 8212

Large, memory intensive systems are usually multi-card implementations and require some form of TTL buffering to provide necessary current and voltage levels. Frequently, 8212s are used for this purpose. The 8212 has the advantage of being able to latch and demultiplex the address bus and provide extra address drive capability at the same time.

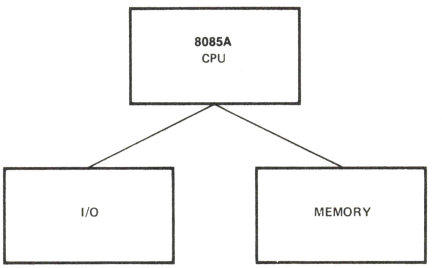
SYSTEM PERFORMANCE

The true benchmark of any microcomputer-based system is the amount of tasks that can be performed by the system in a given period of time. Increasing speed of CPU instruction execution has been the common approach to increasing system throughput but this puts a greater strain on the memory access requirement and bus operation than is usually practical for most applications. A much more desirable method would be to distribute the task-load to peripheral devices.



DISTRIBUTED PROCESSING

The concept of distributed task processing is not new to the computer designer, but until recently little if any task distribution was available to the microcomputer user. The use of the new programmable MCS-80/85 peripherals can relieve the central processor of many of the bookkeeping I/O and timing tasks that would otherwise have to be handled by system software.



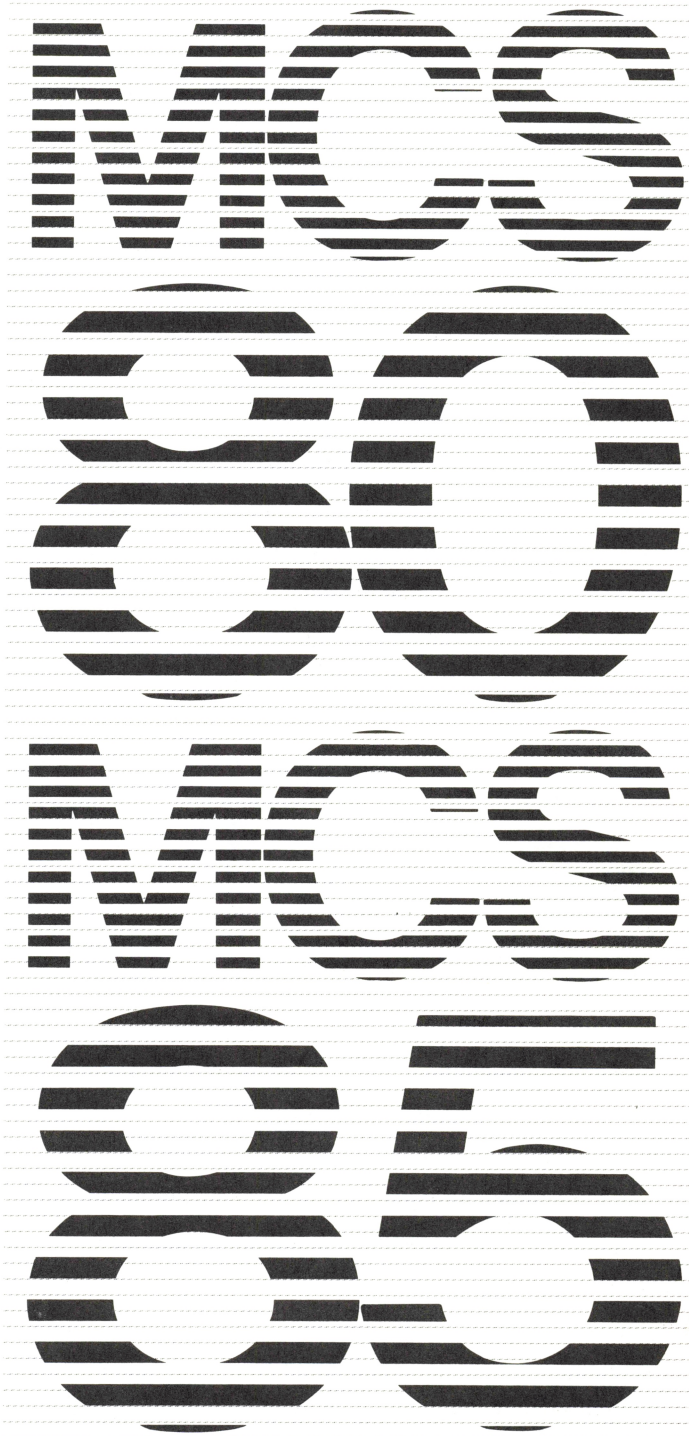
INSTRUCTION CYCLE/ACCESS TIME

The basic instruction cycle of the 8085A is 1.3 microseconds, the same speed as the 8080A-1. A close look at the MCS-85 bus operation shows that the access requirement for this speed is only 575 nanoseconds. The MCS-80 access requirements for this speed would be under 300 nanoseconds. This illustrates the efficiency and improved timing margins of the MCS-85 bus structure. The new 8085A-2, a high-speed selected version of the 8085A with a .8 microsecond instruction cycle, provides a 60% performance improvement over the standard 8085A.

CONCLUSIONS: THROUGHPUT/COST

When a total system throughput/cost analysis is taken, the MCS-85 system with its advanced processor will yield the most cost-effective, reliable and producible system.

Chapter 2
8085A Functional Description



CHAPTER 2
8085A FUNCTIONAL DESCRIPTION

2.1 WHAT THE 8085A IS

The 8085A is an 8-bit general-purpose microprocessor that is very cost-effective in small systems because of its extraordinarily low hardware overhead requirements. At the same time it is capable of accessing up to 64K bytes of memory and has status lines for controlling large systems.

2.2 WHAT'S IN THE 8085A

In the 8085A microprocessor are contained the functions of clock generation, system bus control, and interrupt priority selection, in addition to execution of the instruction set. (See Figure 2-1.) The 8085A transfers data on an 8-bit, bidirectional 3-state bus (AD_{0-7}) which is time-multiplexed so as to also transmit the eight lower-order address bits. An additional eight lines (A_{8-15}) expand the MCS-85 system memory addressing capability to 16 bits, thereby allowing 64K bytes of memory to be accessed directly by the CPU. The 8085A CPU (central processing unit) generates control signals that can be used to select appropriate external devices and functions to perform READ and WRITE operations and also to select memory or I/O ports. The 8085A can address up to 256 different I/O locations. These addresses have the same numerical values (00 through FFH) as the first 256 memory addresses; they are distinguished by means of the IO/$\overline{M}$ output from the CPU. You may also choose to address I/O ports as memory locations (i.e., memory-map the I/O, Section 3.2).

2.2.1 Registers

The 8085A, like the 8080, is provided with internal 8-bit registers and 16-bit registers. The 8085A has eight addressable 8-bit registers. Six of them can be used either as 8-bit registers or as 16-bit register pairs. Register pairs are treated as though they were single, 16-bit registers; the high-order byte of a pair is located in the first register and the low-order byte is located in the second. In addition to the register pairs, the 8085A contains two more 16-bit registers.

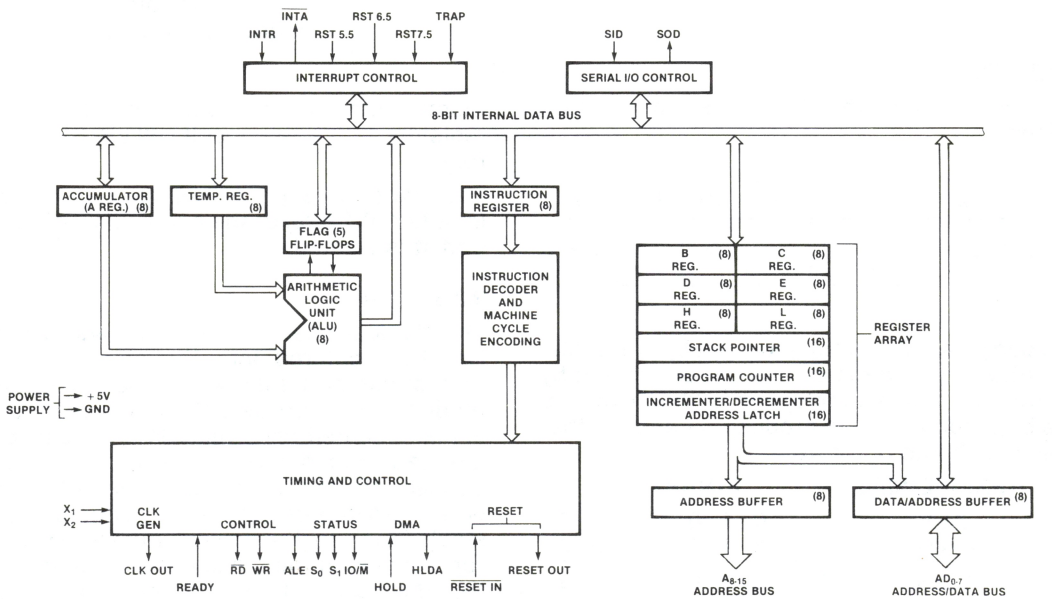


FIGURE 2-1 8085A CPU FUNCTIONAL BLOCK DIAGRAM

The 8085A's CPU registers are distinguished as follows:

- The **accumulator** (ACC or A Register) is the focus of all of the accumulator instructions (Table 4-1), which include arithmetic, logic, load and store, and I/O instructions. It is an 8-bit register only. (However, see **Flags,** in this list.)
- The **program counter** (PC) always points to the memory location of the next instruction to be executed. It always contains a 16-bit address.
- **General-purpose registers** BC, DE, and HL may be used as six 8-bit registers or as three 16-bit registers, interchangeably, depending on the instruction being performed. HL functions as a **data pointer** to reference memory addresses that are either the sources or the destinations in a number of instructions. A smaller number of instructions can use BC or DE for indirect addressing.
- The **stack pointer** (SP) is a special data pointer that always points to the stack top (next available stack address). It is an indivisible 16-bit register.
- The **flag register** contains five one-bit flags, each of which records processor status information and may also control processor operation. (See following paragraph.)

2.2.2 Flags

The five flags in the 8085A CPU are shown below:

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
S	Z		AC		P		CY

The **carry flag** (CY) is set and reset by arithmetic operations. Its status can be directly tested by a program. For example, the addition of two one-byte numbers can produce an answer that does not fit into one byte:

HEXIDECIMAL	BINARY
AEH	1 0 1 0 1 1 1 0
+74H	0 1 1 1 0 1 0 0
122H	1 0 0 1 0 0 0 1 0

Carry bit sets carry flag to 1

An addition operation that results in an overflow out of the high-order bit of the accumulator sets the carry flag. An addition operation that does not result in an overflow clears the carry flag. (See 8080/8085 Assembly Language Programming Manual for further details.) The carry flag also acts as a "borrow" flag for subtract operations.

The **auxiliary carry flag** (AC) indicates overflow out of bit 3 of the accumulator in the same way that the carry flag indicates overflow out of bit 7. This flag is commonly used in BCD (binary coded decimal) arithmetic.

The **sign flag** is set to the condition of the most significant bit of the accumulator following the execution of arithmetic or logic instructions. These instructions use bit 7 of data to represent the sign of the number contained in the accumulator. This permits the manipulation of numbers in the range from −128 to +127.

The **zero flag** is set if the result generated by certain instructions is zero. The zero flag is cleared if the result is not zero. A result that has a carry but has a zero answer byte in the accumulator will set both the carry flag and the zero flag. For example,

HEXADECIMAL	BINARY
A7H	1 0 1 0 0 1 1 1
+59H	+ 0 1 0 1 1 0 0 1
100H	1 0 0 0 0 0 0 0 0

Carry bit

Eight zero bits set zero flag to 1

Incrementing or decrementing certain CPU registers with a zero result will also set the zero flag.

The **parity flag** (P) is set to 1 if the parity (number of 1-bits) of the accumulator is even. If odd, it is cleared.

2.2.3 Stack

The stack pointer maintains the address of the last byte entered into the stack. The stack pointer can be initialized to use any portion of read-write memory as a stack. The stack pointer is decremented each time data is pushed onto the stack and is incremented each time data is popped off the stack (i.e., the stack grows downward in terms of memory address, and the stack "top" is the lowest numerical address represented in the stack currently in use). Note that the stack pointer is always incremented or decremented by two bytes since all stack operations apply to register pairs.

2.2.4 Arithmetic-Logic Unit (ALU)

The ALU contains the accumulator and the flag register (described in Sections 2.2.1 and 2.2.2) and some temporary registers that are inaccessible to the programmer.

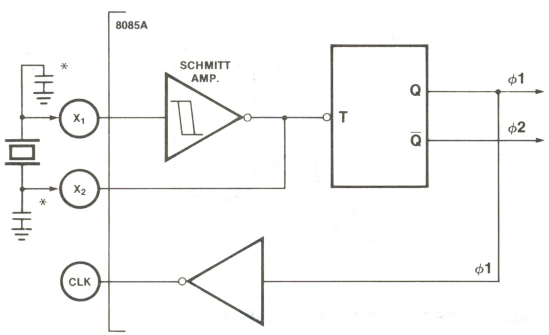
Arithmetic, logic, and rotate operations are performed by the ALU. The results of these operations can be deposited in the accumulator, or they can be transferred to the internal data bus for use elsewhere.

2.2.5 Instruction Register and Decoder

During an instruction fetch, the first byte of an instruction (containing the opcode) is transferred from the internal bus to the 8-bit instruction register. (See Figure 2-1.) The contents of the instruction register are, in turn, available to the instruction decoder. The output of the decoder, gated by timing signals, controls the registers, ALU, and data and address buffers. The outputs of the instruction decoder and internal clock generator generate the state and machine cycle timing signals.

2.2.6 Internal Clock Generator

The 8085A CPU incorporates a complete clock generator on its chip, so it requires only the addition of a quartz crystal to establish timing for its operation. (It will accept an external clock input at its X_1 input instead, however.) A suitable crystal for the standard 8085A must be parallel-resonant at a fundamental of 6.25 MHz or less, twice the desired internal clock frequency. The 8085A-2 will operate with crystal of up to 10 MHz. The functions of the 8085A internal clock generator are shown in Figure 2-2. A Schmitt trigger is used interchangeably as oscillator or as input conditioner, depending upon whether a crystal or an external source is used. The clock circuitry generates two nonoverlapping internal clock signals, ϕ_1 and ϕ_2 (see Figure 2-2). ϕ_1 and ϕ_2 control the internal timing of the 8085A and are not directly available on the outside of the chip. The external pin CLK is a buffered, inverted version of ϕ_1. CLK is half the frequency of the crystal input signal and may be used for clocking other devices in the system.



*EXTERNAL CAPACITORS REQUIRED ONLY FOR CRYSTAL FREQUENCIES ≤4MHz.

FIGURE 2-2 8085A CLOCK LOGIC

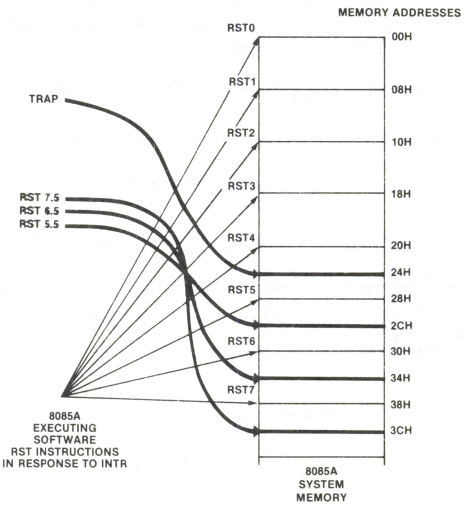


FIGURE 2-3 8085A HARDWARE AND SOFTWARE RST BRANCH LOCATIONS

2.2.7 Interrupts

The five hardware interrupt inputs provided in the 8085A are of three types. INTR is identical with the 8080A INT line in function; i.e., it is maskable (can be enabled or disabled by EI or DI software instructions), and causes the CPU to fetch in an RST instruction, externally placed on the data bus, which vectors a branch to any one of eight fixed memory locations (Restart addresses). (See Figure 2-3.) INTR can also be controlled by the 8259 programmable interrupt controller, which generates CALL instructions instead of RSTs, and can thus vector operation of the CPU to a preprogrammed subroutine located anywhere in your system's memory map. The RST 5.5, RST 6.5, and RST 7.5 hardware interrupts are different in function in that they are maskable through the use of the SIM

instruction, which enables or disables these interrupts by clearing or setting corresponding mask flags based on data in the accumulator. (See Figure 2-4.) You may read the status of the interrupt mask previously set by peforming a RIM instruction. Its execution loads into the accumulator the following information. (See Figure 2-5.)

- Current interrupt mask status for the RST 5.5, 6.5, and 7.5 hardware status.
- Current interrupt enable flag status (except that immediately following TRAP, the IE flag status **preceding** that interrupt is loaded).
- RST 5.5, 6.5, and 7.5 interrupts pending.

RST 5.5, 6.5, and 7.5 are also subject to being enabled or disabled by the EI and DI instructions, respectively. INTR, RST 5.5, and RST 6.5 are level-sensitive, meaning that these inputs may be acknowledged by the processor when they are held at a high level. RST 7.5 is edge-sensitive, meaning that an internal flip-flop in the 8085A registers the occurrence of an interrupt the instant a rising edge appears on the RST 7.5 input line. This input need not be held high; the flip-flop will remain set until it is cleared by one of three possible actions:

- The 8085A responds to the interrupt, and sends an internal reset signal to the RST 7.5 flip-flop. (See Figure 2-6A.)

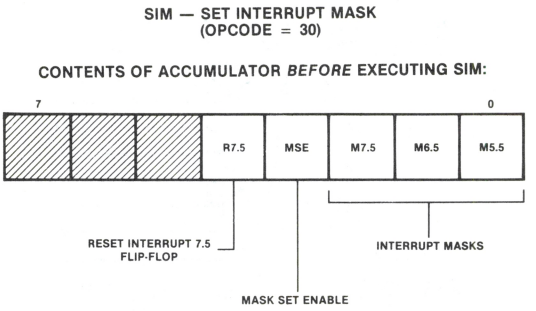


FIGURE 2-4 INTERRUPT MASKS SET USING SIM INSTRUCTION

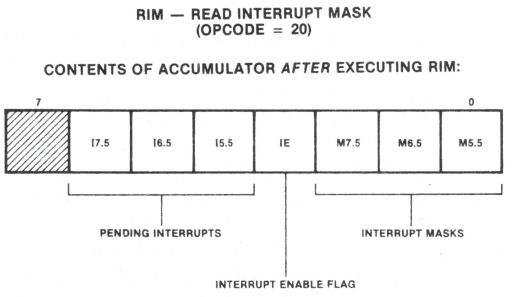


FIGURE 2-5 RIM — READ INTERRUPT MASK

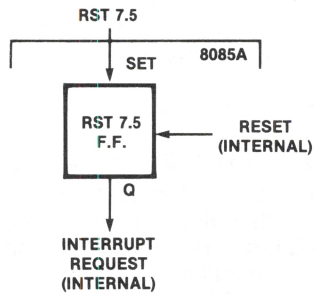


FIGURE 2-6A RST 7.5 FLIP FLOP

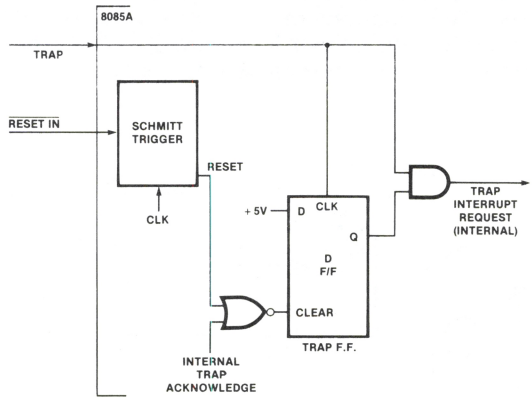


FIGURE 2-6B TRAP INTERRUPT INPUTS

FIGURE 2-6 RST 7.5 AND TRAP INTERRUPT INPUTS

- The 8085A, before responding to the RST 7.5 interrupt, receives a RESET IN signal from an external source; this also activates the internal reset.

- The 8085A executes a SIM instruction, with accumulator bit 4 previously set to 1. (See Figure 2-4.)

The third type of hardware interrupt is TRAP. This input is not subject to any mask or interrupt enable/disable instruction. The receipt of a positive-going edge on the TRAP input triggers the processor's hardware interrupt sequence, but the pulse must be held high until acknowledged internally (see Figure 2-6B).

The sampling of all interrupts occurs on the descending edge of CLK, one cycle before the end of the instruction in which the interrupt input is activated. To be recognized, a valid interrupt must occur at least 160 ns before sampling time in the 8085A, or 150 ns in the 8085A-2. This means that to guarantee being recognized, RST 5.5 and 6.5 and TRAP need to be held on for at least 17 clock states plus 160 ns (150 for 8085A-2), assuming that the interrupt might arrive just barely too late to be acknowledged during a particular instruction, and that the following instruction might be an 18-state CALL. This timing assumes no WAIT or HOLD cycles are used.

The way interrupt masks are set and read is described in Chapter 4 under the RIM (read interrupt mask) and SIM (set interrupt mask) instruction listings. Interrupt functions and their priorities are shown in the table that follows.

Name	Priority	Address (1) Branched to when interrupt occurs	Type Trigger
TRAP	1	24H	Rising edge AND high level until sampled
RST 7.5	2	3CH	Rising edge (latched)
RST 6.5	3	34H	High level until sampled
RST 5.5	4	2CH	High level until sampled
INTR	5	(2)	High level until sampled

NOTES:
(1) In the case of TRAP and RST 5.5-7.5, the contents of the Program Counter are pushed onto the stack before the branch occurs.
(2) Depends on the instruction that is provided to the 8085A by the 8259 or other circuitry when the interrupt is acknowledged.

2.2.8 Serial Input and Output

The SID and SOD pins help to minimize chip count in small systems by providing for easy interface to a serial port using software for timing and for coding and decoding of the data. Each time a RIM instruction is executed, the status of the SID pin is read into bit 7 of the accumulator. RIM is thus a dual-purpose instruction. (See Chapter 4.) In similar fashion, SIM is used to latch bit 7 of the accumulator out to the SOD output via an internal flip-flop, providing that bit 6 of the accumulator is set to 1. (See Figure 2-7.) Section 2.3.8 describes SID and SOD timing.

SID can also be used as a general purpose TEST input and SOD can serve as a one-bit control output.

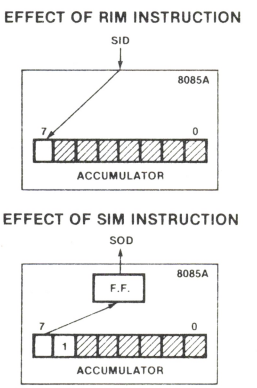


FIGURE 2-7 EFFECT OF RIM AND SIM INSTRUCTIONS ON SERIAL DATA LINES

2.3 HOW THE MCS-85 SYSTEM WORKS

The 8085A CPU generates signals that tell peripheral devices what type of information is on the multiplexed Address/Data bus and from that point on the operation is almost identical to the MCS-80™ CPU Group. A multiplexed bus structure was chosen because it freed device pins so that more functions could be integrated on the 8085A and other components of the family. The multiplexed bus is designed to allow complete compatibility to existing peripheral components with improved timing margins and access requirements. (See Figure 2-8.)

To enhance the system integration of MCS-85, several special components with combined memory and I/O were designed. These new devices directly interface to the multiplexed bus of the 8085A. The pin locations of the 8085A and the special peripheral components are assigned to minimize PC board area and to allow for efficient layout. The details on peripheral components are contained in subsequent paragraphs of this chapter and in Chapters 5 and 6.

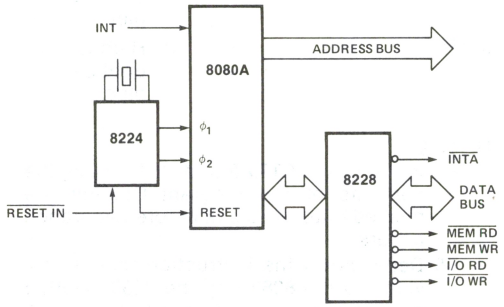


FIGURE 2-8A MCS-80™ CPU GROUP

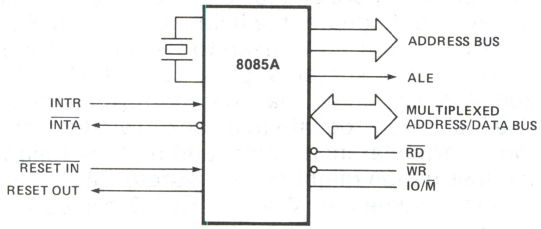


FIGURE 2-8B MCS-85™ CPU/8085A (MCS-80 COMPATIBLE FUNCTIONS)

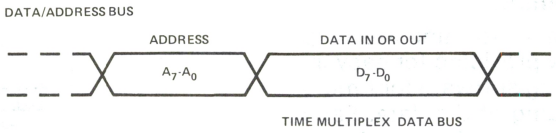


FIGURE 2-8C MULTIPLEXED BUS TIMING

FIGURE 2-8 BASIC CPU FUNCTIONS

2.3.1 Multiplexed Bus Cycle Timing

The execution of any 8085A program consists of a sequence of READ and WRITE operations, of which each transfers a byte of data between the 8085A and a particular memory or I/O address. These READ and WRITE operations are the only communication between the processor and the other components, and are all that is necessary to execute any instruction or program.

Each READ or WRITE operation of the 8085A is referred to as a machine cycle. The execution of each instruction by the 8085A consists of a sequence of from one to five machine cycles, and each machine cycle consists of a minimum of from three to six clock cycles (also referred to as T states). Consider the case of the Store Accumulator Direct (STA) instruction, shown in Figure 2-9. The STA instruction causes the contents of the accumulator to be stored at the direct address specified in the second and third bytes of the instruction. During the first machine cycle (M_1), the CPU puts the contents of the program counter (PC) on the address bus and performs a MEMORY READ cycle to read from memory the opcode of the next instruction (STA). The M_1 machine cycle is also referred to as the OPCODE FETCH cycle, since it fetches the operation code of the next instruction. In the fourth clock cycle (T_4) of M_1, the CPU interprets the data read in and recognizes it as the opcode of the STA instruction. At this point the CPU knows that it must do three more machine cycles (two MEMORY READs and one MEMORY WRITE) to complete the instruction.

The 8085A then increments the program counter so that it points to the next byte of the instruction and performs a MEMORY READ machine cycle (M_2) at address (PC + 1). The accessed memory places the addressed data on the data bus for the CPU. The 8085A temporarily stores this data (which is the low-order byte of the direct address) internally in the CPU. The 8085A again increments the program counter to location (PC + 2) and reads from memory (M_3) the next byte of data, which is the high-order byte of the direct address.

At this point, the 8085A has accessed all three bytes of the STA instruction, which it must now execute. The execution consists of placing the data accessed in M_2 and M_3 on the address bus, then placing the contents of the accumulator on the data bus, and then performing a MEMORY WRITE machine cycle (M_4). When M_4 is finished, the CPU will fetch (M_1) the first byte of the next instruction and continue from there.

State Transition Sequence

As the preceding example shows, the execution of an instruction consists of a series of machine cycles whose nature and sequence is determined by the opcode accessed in the M_1

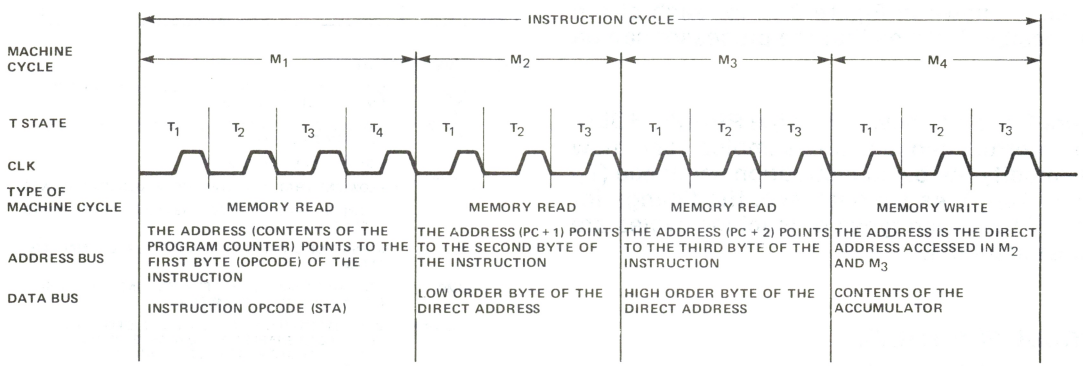


FIGURE 2-9 CPU TIMING FOR STORE ACCUMULATOR DIRECT (STA) INSTRUCTION

MACHINE CYCLE		STATUS			CONTROL		
		IO/$\overline{M}$	S1	S0	$\overline{RD}$	$\overline{WR}$	$\overline{INTA}$
OPCODE FETCH	(OF)	0	1	1	0	1	1
MEMORY READ	(MR)	0	1	0	0	1	1
MEMORY WRITE	(MW)	0	0	1	1	0	1
I/O READ	(IOR)	1	1	0	0	1	1
I/O WRITE	(IOW)	1	0	1	1	0	1
INTR ACKNOWLEDGE	(INA)	1	1	1	1	1	0
BUS IDLE	(BI): DAD	0	1	0	1	1	1
	INA(RST/TRAP)	1	1	1	1	1	1
	HALT	TS	0	0	TS	TS	1

0 = Logic "0" 1 = Logic "1" TS = High Impedance X = Unspecified

FIGURE 2-10 8085A MACHINE CYCLE CHART

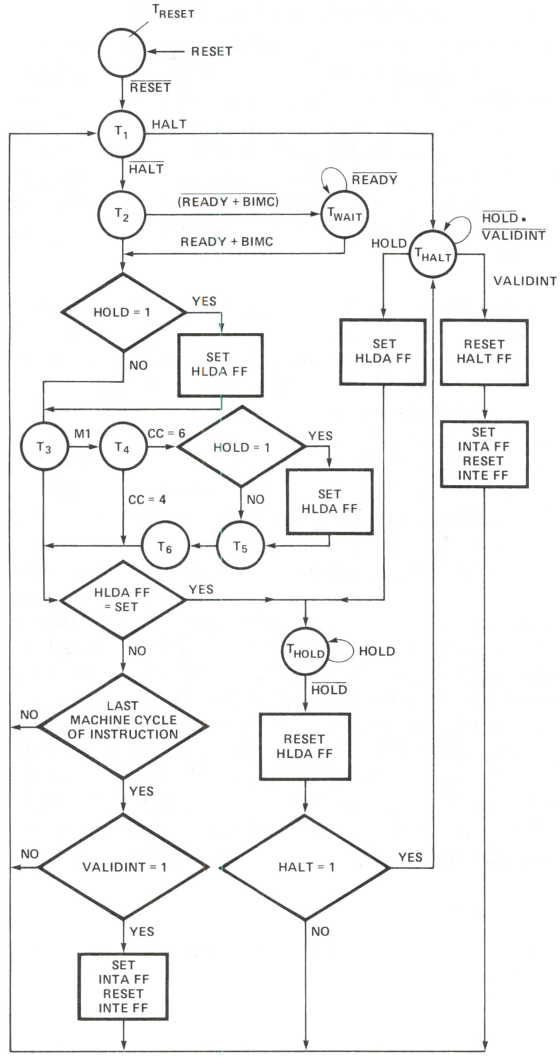
machine cycle. While no one instruction cycle will consist of more than five machine cycles, every machine cycle will be one of the seven types listed in Figure 2-10. These seven types of machine cycles can be differentiated by the state of the three status lines (IO/$\overline{M}$, S_0, and S_1) and the three control signals ($\overline{RD}$, $\overline{WR}$, and $\overline{INTA}$).

Most machine cycles consist of three T states, (cycles of the CLK output) with the exception of OPCODE FETCH, which normally has either four or six T states. The actual number of states required to perform any instruction depends on the instruction being executed, the particular machine cycle within the instruction cycle, and the number of WAIT and HOLD states inserted into each machine cycle through the use of the READY and HOLD inputs of the 8085A. The state transition diagram in Figure 2-11 illustrates how the 8085A proceeds in the course of a machine cycle. The state of various status and control signals, as well as the system buses, is shown in Figure 2-12 for each of the ten possible T states that the processor can be in.

Figure 2-11 also shows when the READY, HOLD, and interrupt signals are sampled, and how they modify the basic instruction sequence (T_1-T_6 and T_{WAIT}). As we shall see, the timings for each of the seven types of machine cycles are almost identical.

OPCODE FETCH (OF):

The OPCODE FETCH (OF) machine cycle is unique in that it has more than three clock cycles. This is because the CPU must interpret the opcode accessed in T_1, T_2, and T_3 before it can decide what to do next.



NOTE: SYMBOL DEFINITION

- T_x = CPU STATE T_x. ALL CPU STATE TRANSITIONS OCCUR ON THE FALLING EDGE OF CLK.
- X = A DECISION (X) THAT DETERMINES WHICH OF SEVERAL ALTERNATIVE PATHS TO FOLLOW.
- X = PERFORM THE ACTION X.
- → = FLOWLINE THAT INDICATES THE SEQUENCE OF EVENTS.
- X → = FLOWLINE THAT INDICATES THE SEQUENCE OF EVENTS IF CONDITION X IS TRUE.
- CC = NUMBER OF CLOCK CYCLES IN THE CURRENT MACHINE CYCLE.
- BIMC = "BUS IDLE MACHINE CYCLE" = MACHINE CYCLE WHICH DOESN'T USE THE SYSTEM BUS.
- VALIDINT = "VALID INTERRUPT" – AN INTERRUPT IS PENDING THAT IS BOTH ENABLED AND UNMASKED (MASKING ONLY APPLIES FOR RST 5.5, 6.5, AND 7.5 INPUTS).
- HLDA FF = INTERNAL HOLD ACKNOWLEDGE FLIP FLOP. NOTE THAT THE 8085A SYSTEM BUSES ARE 3-STATED ONE CLOCK CYCLE AFTER THE HLDA FLIP FLOP IS SET.

FIGURE 2-11 8085A CPU STATE TRANSITION

Machine State	Status & Buses				Control		
	S1,S0	IO/$\overline{M}$	A_8-A_{15}	AD_0-AD_7	$\overline{RD}$,$\overline{WR}$	$\overline{INTA}$	ALE
T_1	X	X	X	X	1	1	1†
T_2	X	X	X	X	X	X	0
T_{WAIT}	X	X	X	X	X	X	0
T_3	X	X	X	X	X	X	0
T_4	1	0*	X	TS	1	1	0
T_5	1	0*	X	TS	1	1	0
T_6	1	0*	X	TS	1	1	0
T_{RESET}	X	TS	TS	TS	TS	1	0
T_{HALT}	0	TS	TS	TS	TS	1	0
T_{HOLD}	X	TS	TS	TS	TS	1	0

0 = Logic "0" 1 = Logic "1" TS = High Impedance X = Unspecified

†ALE not generated during 2nd and 3rd machine cycles of DAD instruction.

*IO/$\overline{M}$ = 1 during T_4-T_6 states of RST and INA cycles.

FIGURE 2-12 8085A MACHINE STATE CHART

Figure 2-13 shows the timing relationships for an OF machine cycle. The particular instruction illustrated is DCX, whose timing for OF differs from other instructions in that it has six T states, while some instructions require only four T states for OF. In this discussion, as well as the following discussions, only the relative timing of the signals will be discussed; for the actual timings, refer to the data sheets of the individual parts in Chapters 5 and 6.

The first thing that the 8085A does at the beginning of every machine cycle is to send out three status signals (IO/$\overline{M}$, S1, S0) that define what type of machine cycle is about to take place. The IO/$\overline{M}$ signal identifies the machine cycle as being either a memory reference or input/output operation. The S1 status signal identifies whether the cycle is a READ or WRITE operation. The S0 and S1 status signals can be used together (see Figure 2-10) to identify READ, WRITE, or OPCODE FETCH machine cycles as well as the HALT state. Referring to Figure 2-13, the 8085A will send out IO/$\overline{M}$ = 0, S1 = 1, S0 = 1 at the beginning of the machine cycle to identify it as a READ from a memory location to obtain an opcode; in other words, it identifies the machine cycle as an OPCODE FETCH cycle.

The 8085A also sends out a 16-bit address at the beginning of every machine cycle to identify the particular memory location or I/O port that the machine cycle applies to. In the case of an OF cycle, the contents of the program counter is placed on the address bus. The high order byte (PCH) is placed on the A_8-A_{15} lines, where it will stay until at least T_4. The low order byte (PCL) is placed on the AD_0-AD_7 lines, whose three-state drivers are enabled if not found already on. Unlike the upper address lines, however, the information on the lower address lines will remain there for only one clock cycle, after which the drivers will go to their high impedance state, indicated by a dashed line in Figure 2-13. This is necessary because the AD_0-AD_7 lines are time mulitplexed between the address and data buses. During T_1 of every machine cycle, AD_0-AD_7 output the lower 8-bits of address after which AD_0-AD_7 will either output the desired data for a WRITE operation or the drivers will float (as is the case for the OF cycle), allowing the external device to drive the lines for a READ operation.

Since the address information on AD_0-AD_7 is of a transitory nature, it must be latched either internally in special multiplexed-bus components like the 8155 or externally in parts like the 8212 8-bit latch. (See Chapter 3.) The 8085A provides a special timing signal, ADDRESS LATCH ENABLE (ALE), to facilitate the latching of A_0-A_7; ALE is present during T_1 of every machine cycle.

After the status signals and address have been sent out and the AD_0-AD_7 drivers have been disabled, the 8085A provides a low level on $\overline{RD}$ to enable the addressed memory device. The device will then start driving the AD_0-AD_7 lines; this is indicated by the dashed line turning into a solid line in Figure 2-13. After a period of time (which is the access time of the memory) valid data will be present on AD_0-AD_7. The 8085A during T_3 will load the memory data on AD_0-AD_7 into its instruction register and then raise $\overline{RD}$ to the high level, disabling the addressed memory device. At this point, the 8085A will have finished accessing the opcode of the instruction. Since this is the first machine cycle (M_1) of the instruction, the CPU will automatically step to T_4, as shown in Figure 2-11.

During T_4, the CPU will decode the opcode in the instruction register and decide whether to enter T_5 on the next clock or to start a new machine cycle and enter T_1. In the case of the DCX instruction shown in Figure 2-13, it will enter T_5 and then T_6 before going to T_1.

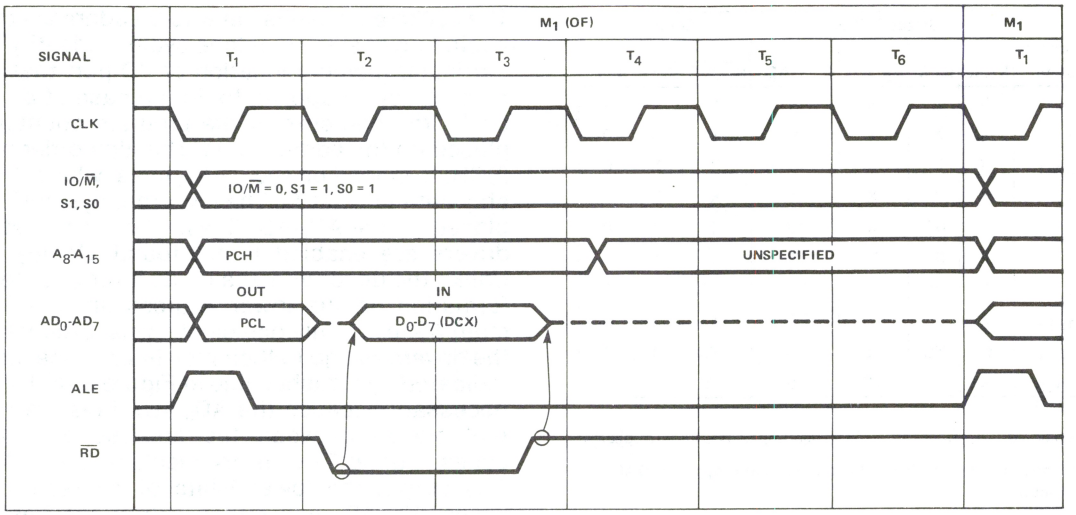


FIGURE 2-13 OPCODE FETCH MACHINE CYCLE (OF DCX INSTRUCTION)

During T_5 and T_6, of DCX, the CPU will decrement the designated register. Since the A_8-A_{15} lines are driven by the address latch circuits, which are part of the incrementer/decrementer logic, the A_8-A_{15} lines may change during T_5 and T_6. Because the value of A_8-A_{15} can vary during T_4-T_6, it is most important that all memory and I/O devices on the system bus qualify their selection with $\overline{RD}$. If they don't use $\overline{RD}$, they may be spuriously selected. Moreover, with a linear selection technique (Chapter 3), two or more devices could be simultaneously enabled, which could be potentially damaging. The generation of spurious addresses can also occur momentarily at address bus transitional periods in T_1. Therefore, the selection of all memory and I/O devices must be qualified with $\overline{RD}$ or $\overline{WR}$. Many new memory devices like the 8155 and 8355 have the $\overline{RD}$ input that internally is used to enable the data bus outputs, removing the need for externally qualifying the chip enable input with $\overline{RD}$.

Figure 2-14 is identical to Figure 2-13 with one exception, which is the use of the READY line. As we can see in Figure 2-11, when the CPU is in T_2, it examines the state of the READY line. If the READY line is high, the CPU will proceed to T_3 and finish executing the instruction. If the READY line is low, however, the CPU will enter T_{WAIT} and stay there indefinitely until READY goes high. When the READY line does go high, the CPU will exit T_{WAIT} and enter T_3, in order to complete the machine cycle. As shown in Figure 2-14, the external effect of using the READY line is to preserve the exact state of the processor signals at the end of T_2 for an integral number of clock periods, before finishing the machine cycle. This "stretching" of the system timing has the further effect of increasing the allowable access time for memory or I/O devices. By inserting T_{WAIT} states, the 8085A can accommodate even the slowest of memories. Another common use of the READY line is to singe-step the processor with a manual switch.

2.3.2 Read Cycle Timing

MEMORY READ (MR):

Figure 2-15 shows the timing of two successive MEMORY READ (MR) machine cycles, the first without a T_{WAIT} state and the second with one T_{WAIT} state. The timing during T_1-T_3 is absolutely identical to the OPCODE FETCH machine cycle, with the exception that the status sent out during T_1 is $IO/\overline{M} = 0$, $S1 = 1$, $S0 = 0$, identifying the cycles as a READ from a memory location. This differs from Figure 2-13 only in that $S0 = 1$ for an OF cycle, identifying that cycle as an OPCODE FETCH operation. Otherwise, the two cycles are identical during T_1-T_3.

A second difference occurs at the end of T_3. As shown in Figure 2-11, the CPU always goes to T_4 from T_3 during M_1, which is always an OF cycle. During all other machine cycles, the CPU will always go from T_3 to T_1 of the next machine cycle.

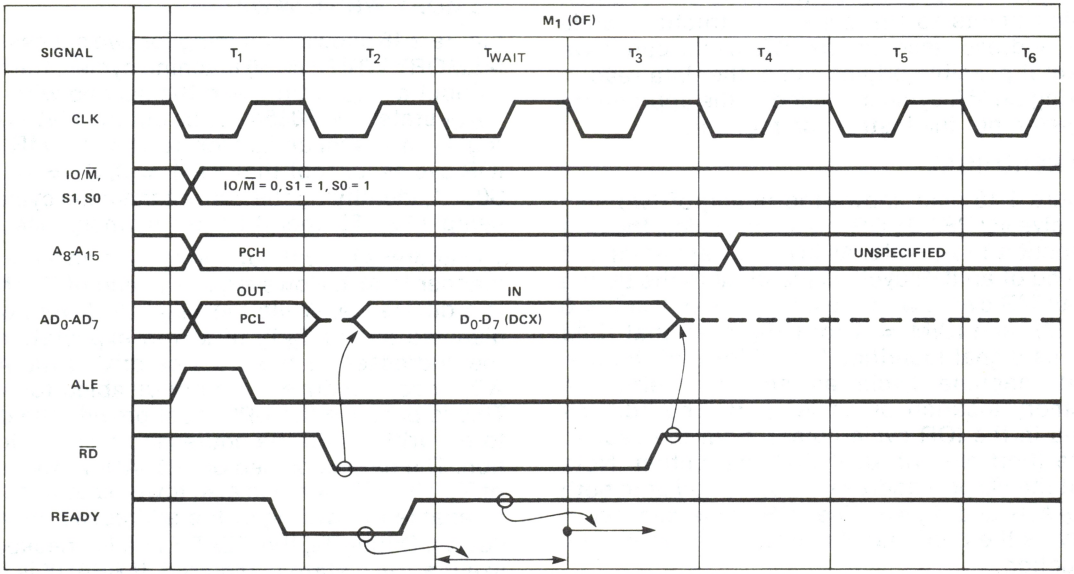


FIGURE 2-14 OPCODE FETCH MACHINE CYCLE WITH ONE WAIT STATE

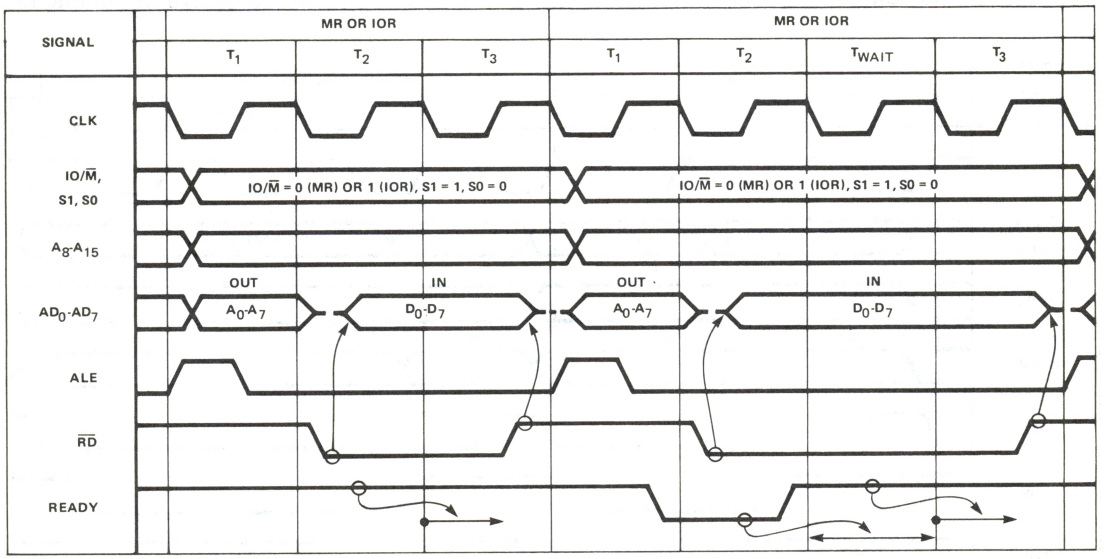


FIGURE 2-15 MEMORY READ (OR I/O READ) MACHINE CYCLES (WITH AND WITHOUT WAIT STATES)

The memory address used in the OF cycle is always the contents of the program counter, which points to the current instruction, while the address used in the MR cycle can have several possible origins. Also, the data read in during an MR cycle is placed in the appropriate register, not the instruction register.

I/O READ (IOR):

Figure 2-15 also shows the timing of two successive I/O READ (IOR) machine cycles, the first without a T_{WAIT} state. As is readily apparent, the timing of an IOR cycle is identical to the timing of an MR cycle, with the exception of $IO/\overline{M} = 0$ for MR and $IO/\overline{M} = 1$ for IOR; recall that $IO/\overline{M}$ status signal identifies the address of the current machine cycle as selecting either a memory location or an I/O port. The address used in the IOR cycle comes from the second byte (Port No.) of an INPUT instruction. Note that the I/O port address is duplicated onto both AD_0-AD_7 and A_8-A_{15}. The IOR cycle can occur only as the third machine cycle of an INPUT instruction.

Note that the READY signal can be used to generate T_{WAIT} states for I/O devices as well as memory devices. By gating the READY signal with the proper status lines, one could generate T_{WAIT} states for memory devices only or for I/O devices only. By gating in the address lines, one can further qualify T_{WAIT} state generation by the particular devices being accessed.

2.3.3 WRITE Cycle Timing

MEMORY WRITE (MW):

Figure 2-16 shows the timing for two successive MEMORY WRITE (MW) machine cycles, the first without a T_{WAIT} state, and the second with one T_{WAIT} state. The 8085A sends out the status during T_1 in a similar fashion to the OF, MR and IOR cycles, except that $IO/\overline{M} = 0$, $S1 = 0$, and $S0 = 1$, identifying the current machine cycle as being a WRITE operation to a memory location.

The address is sent out during T_1 in an identical manner to MR. However, at the end of T_1, there is a difference. While the AD_0-AD_7 drivers were disabled during T_2-T_3 of MR in expectation of the addressed memory device driving the AD_0-AD_7 lines, the drivers are not disabled for MW. This is because the CPU must provide the data to be written into the addressed memory location. The data is placed on AD_0-AD_7 at the start of T_2. The $\overline{WR}$ signal is also lowered at this time to enable the writing of the addressed memory device. During T_2, the READY line is checked to see if a T_{WAIT} state is required. If READY is low, T_{WAIT} states are inserted until READY goes high. During T_3, the $\overline{WR}$ line is raised, disabling the addressed memory device and thereby terminating the WRITE operation. The contents of the address and data lines are not changed until the next T_1, which directly follows.

Note that the data on AD_0-AD_7 is not guaranteed to be stable before the falling edge

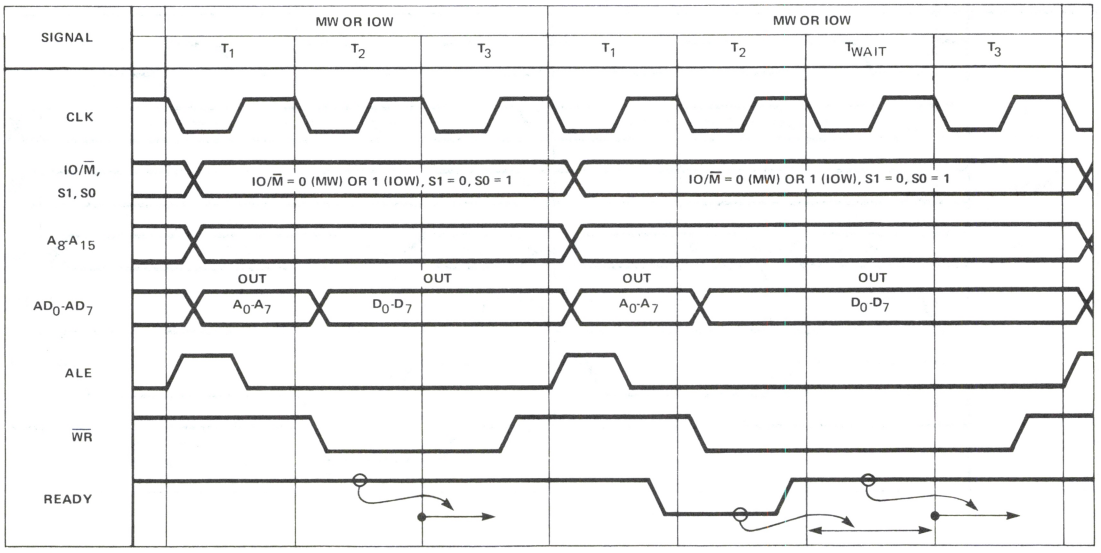


FIGURE 2-16 MEMORY WRITE (OR I/O WRITE) MACHINE CYCLES (WITH AND WITHOUT WAIT STATES)

of $\overline{WR}$. The AD_0-AD_7 lines are guaranteed to be stable both before and after the rising edge of $\overline{WR}$.

I/O WRITE (IOW):

As Figure 2-16 shows, the timing for an I/O WRITE (IOW) machine cycle is the same as an MW machine cycle except that IO/$\overline{M}$ = 0 during the MW cycle and IO/$\overline{M}$ = during the IOW cycle.

As with the IOR cycle discussed previously, the address used in an IOW cycle is the I/O port number which is duplicated on both the high and low bytes of the address bus. In the case of IOW, the port number comes from the second byte of an OUTPUT instruction as the instruction is executed.

2.3.4 Interrupt Acknowledge (INA) Timing

Figures 2-17 and 2-18 (a continuation of 2-17) depict the course of action the CPU takes in response to a high level on the INTR line if the INTE FF (interrupt enable flip-flop) has been set by the EI instruction. The status of the TRAP and RST pins as well as INTR is sampled during the second clock cycle before $M_1 \cdot T_1$. If INTR was the only valid interrupt and if INTE FF is set, then the CPU will reset INTE FF and then enter an INTERRUPT ACKNOWLEDGE (INA) machine cycle. The INA cycle is identical to an OF cycle with two exceptions. $\overline{INTA}$ is sent out instead of $\overline{RD}$. Also, IO/$\overline{M}$ = 1 during INA, whereas IO/$\overline{M}$ = 0 for OF. Although the contents of the program counter are sent out on the address lines, the address lines can be ignored.

When $\overline{INTA}$ is sent out, the external interrupt logic must provide the opcode of an instruction to execute. The opcode is placed on the data bus and read in by the processor. If the opcode is the first byte of a multiple-byte instruction, additional $\overline{INTA}$ pulses will be provided by the 8085A to clock in the remaining bytes. RESTART and CALL instructions are the most

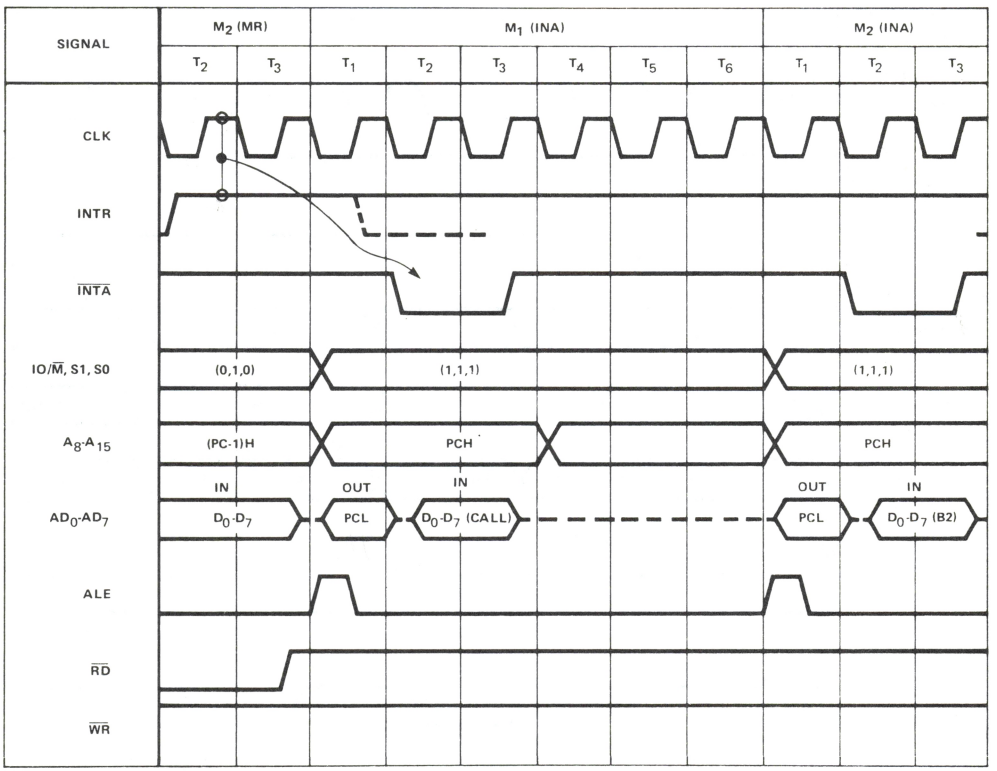


FIGURE 2-17 INTERRUPT ACKNOWLEDGE MACHINE CYCLES (WITH CALL INSTRUCTION IN RESPONSE TO INTR)

logical choices, since they both force the processor to push the contents of the program counter onto the stack before jumping to a new location. In Figure 2-17 it is assumed that a CALL opcode is sent to the CPU during M_1. The CALL opcode could have been placed there by a device like the 8259 programmable interrupt controller.

After receiving the opcode, the processor then decodes it and determines, in this case, that the CALL instruction requires two more bytes. The CPU therefore performs a second INA cycle (M_2) to access the second byte of the instruction from the 8259. The timing of this cycle is identical to M_1, except that it has only three T states. M_2 is followed by another INA cycle (M_3) to access the third byte of the CALL instruction from the 8259.

Now that the CPU has accessed the entire instruction used to acknowledge the interrupt, it will execute that instruction. Note that any instruction could be used (except EI or DI, the instructions which enable or disable interrupts), but the RESTART and CALL instructions are the most logical choices. Also notice that the CPU inhibited the incrementing of the program counter (PC) during the three INA cycles, so that the correct PC value can be pushed onto the stack during M_4 and M_5.

During M_4 and M_5, the CPU performs MEMORY WRITE machine cycles to write the upper and then lower bytes of the PC onto the top of the stack. The CPU then places the two bytes accessed in M_2 and M_3 into the lower and upper bytes of the PC. This has the effect of jumping the execution of the program to the location specified by the CALL instruction.

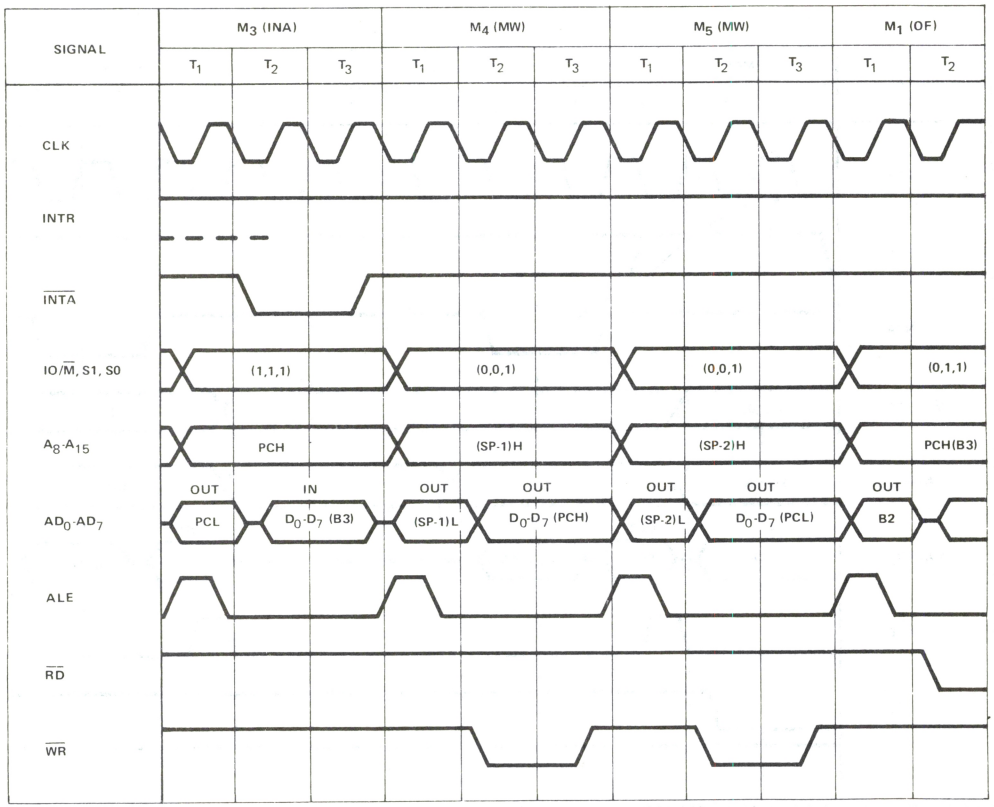


FIGURE 2-18 INTERRUPT ACKNOWLEDGE MACHINE CYCLES (WITH CALL INSTRUCTION IN RESPONSE TO INTR)

2.3.5 Bus Idle (BI) and HALT State

Most machine cycles of the 8085A are associated with either a READ or WRITE operation. There are two exceptions to this rule. The first exception takes place during M_2 and M_3 of the DAD instruction. The 8085A requires six internal T states to execute a DAD instruciton, but it is not desirable to have M_1 be ten (four normal plus six extra) states long. Therefore, the CPU generates two extra machine cycles that do not access either the memory or the I/O. These cycles are referred to as BUS IDLE (BI) machine cycles. In the case of DAD, they are identical to MR cycles except that RD remains high and ALE is not generated. Note that READY is ignored during M_2 and M_3 of DAD.

The other time when the BUS IDLE machine cycle occurs is during the internal opcode generation for the RST or TRAP interrupts. Figure 2-19 illustrates the BI cycle generated in response to RST 7.5. Since this interrupt is rising-edge-triggered, it sets an internal latch; that latch is sampled at the falling edge of the next to the last T-state of the previous instruction. At this point the CPU must generate its own internal RESTART instruction which will (in subsequent machine cycles) cause the processor to push the program counter on the stack and to vector to location 3CH. To do this, it executes an OF machine cycle without issuing RD, generating the RESTART opcode instead. After M_1, the CPU continues execution normally in all respects except that the state of the READY line is ignored during the BI cycle.

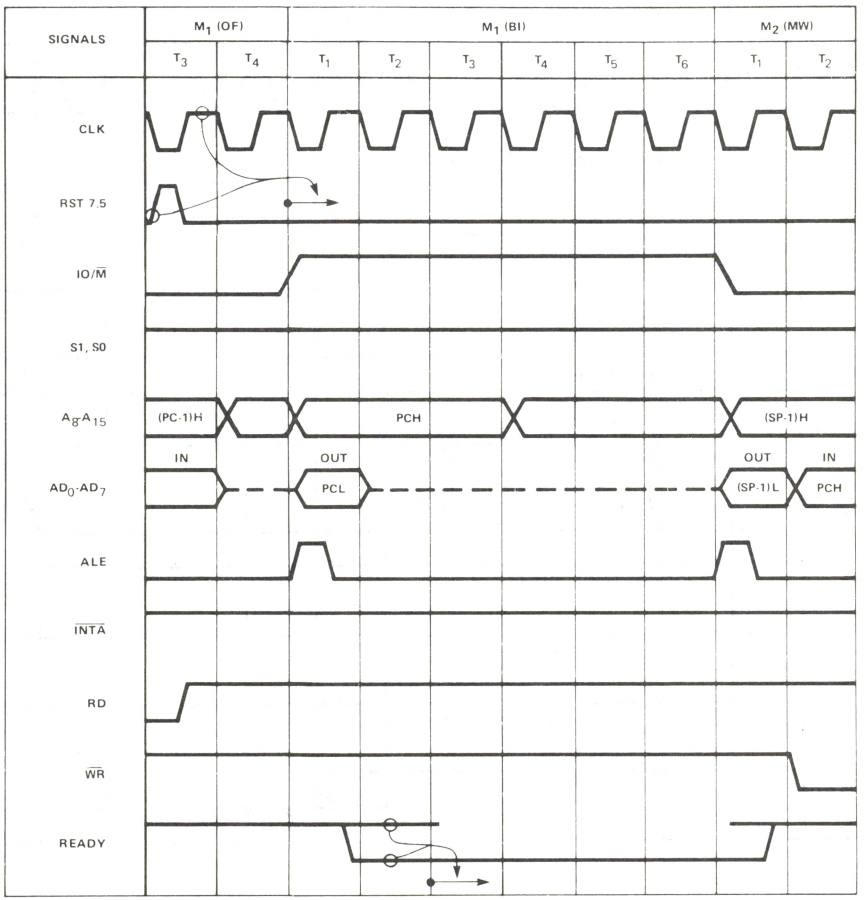


FIGURE 2-19 RST 7.5 BUS IDLE MACHINE CYCLE

Figure 2-20 illustrates the BI cycle generated in response to RST 7.5 when a HALT instruction has just been executed and the CPU is in the T_{HALT} state, with its various signals floating. There are only two ways the processor can completely exit the T_{HALT} state, as shown in Figure 2-11. The first way is for RESET to occur, which always forces the 8085A to T_{RESET}. The second way to exit T_{HALT} permanently is for a valid interrupt to occur, which will cause the CPU to disable further interrupts by resetting INTE FF, and to then proceed to $M_1 \cdot T_1$ of the next instruction. When the HOLD input is activated, the CPU will exit T_{HALT} for the duration of T_{HOLD} and then return to T_{HALT}.

In Figure 2-20 the RST 7.5 line is pulsed during T_{HALT}. Since RST 7.5 is a rising-edge-triggered interrupt, it will set an internal latch which is sampled during CLK = "1" of every T_{HALT} state (as well as during CLK = "1" two T states before any $M_1 \cdot T_1$.) The fact that the latched interrupt was high (assuming that INTE FF = 1 and the RST 7.5 mask = 0) will force the CPU to exit the T_{HALT} state at the end of the next CLK period, and to enter $M_1 \cdot T_1$.

This completes our analysis of the timing of each of the seven types of machine cycles.

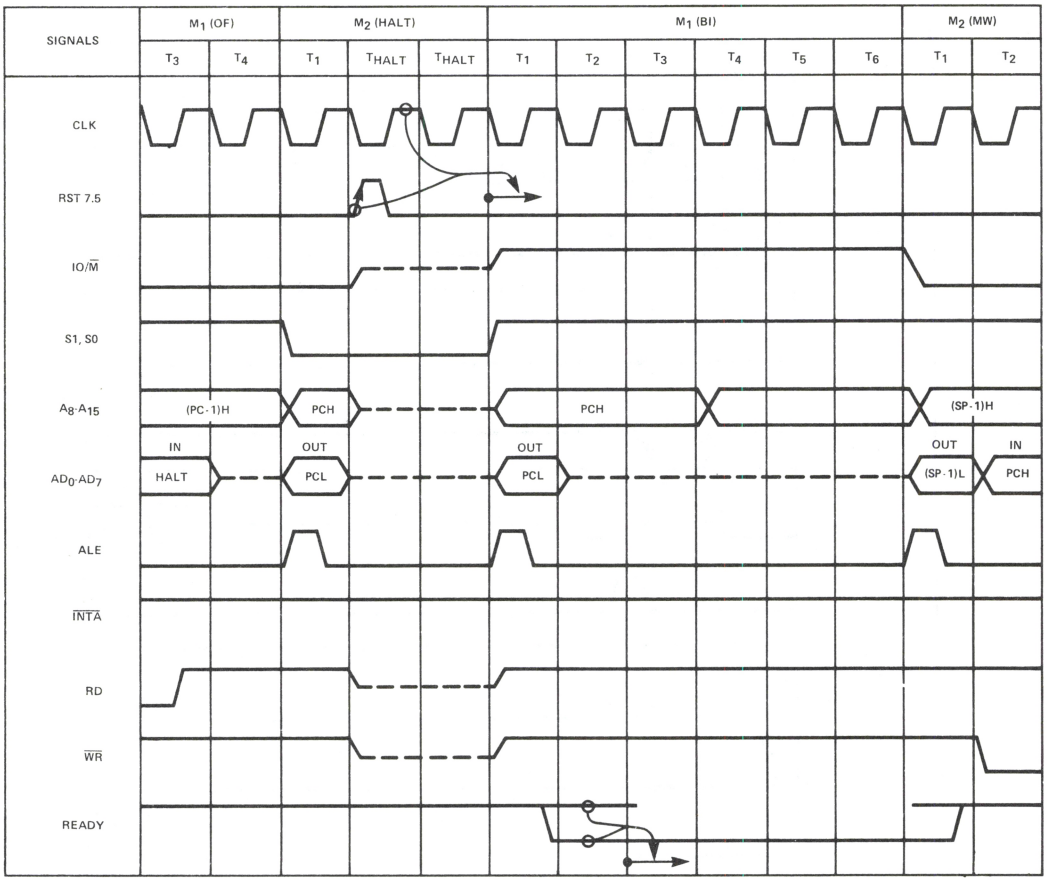


FIGURE 2-20 HALT STATE AND BUS IDLE MACHINE CYCLE RST 7.5 TERMINATES T_{HALT} STATE

2.3.6 HOLD and HALT States

The 8085A uses the T_{HOLD} state to momentarily cease executing machine cycles, allowing external devices to gain control of the bus and peform DMA cycles. The processor internally latches the state of the HOLD line and the unmasked interrupts during CLK = "1" of every T_{HALT} state. If the internal latched HOLD signal is high during CLK = "1" of any T_{HALT} state, the CPU will exit T_{HALT} and enter T_{HOLD} on the following CLK = "1". As shown in Figure 2-21 this will occur even if a valid interrupt occurs simultaneously with the HOLD signal.

The state of the HOLD and the unmasked interrupt lines is latched internally during CLK = 1 of each T_{HOLD} state as well as during T_{HALT} states. If the internal latched HOLD signal is low during CLK = 1, the CPU will exit T_{HOLD} and enter T_{HALT} on the following CLK = 1.

The 8085A accepts the first unmasked, enabled interrupt sampled; thereafter, all interrupt sampling is inhibited. The interrupt thus accepted will inevitably be executed when the CPU exits the HOLD state, even at the expense of holding off higher-priority interrupts (including TRAP). (See Figure 2-22.)

When the CPU is not in T_{HALT} or T_{HOLD}, it internally latches the HOLD line only during CLK = 1 of the last state before T_3 (T_2 or T_{WAIT}) and during CLK = 1 of the last state before T_5 (T_4 of a six T-state M_1). If the internal latched HOLD signal is high during the next CLK = 1, the CPU will enter T_{HOLD} after the following clock. When the CPU is not in T_{HALT} or T_{HOLD}, it will internally latch the state of the unmasked interupts only during CLK of the next to the last state before each $M_1 \cdot T_1$.

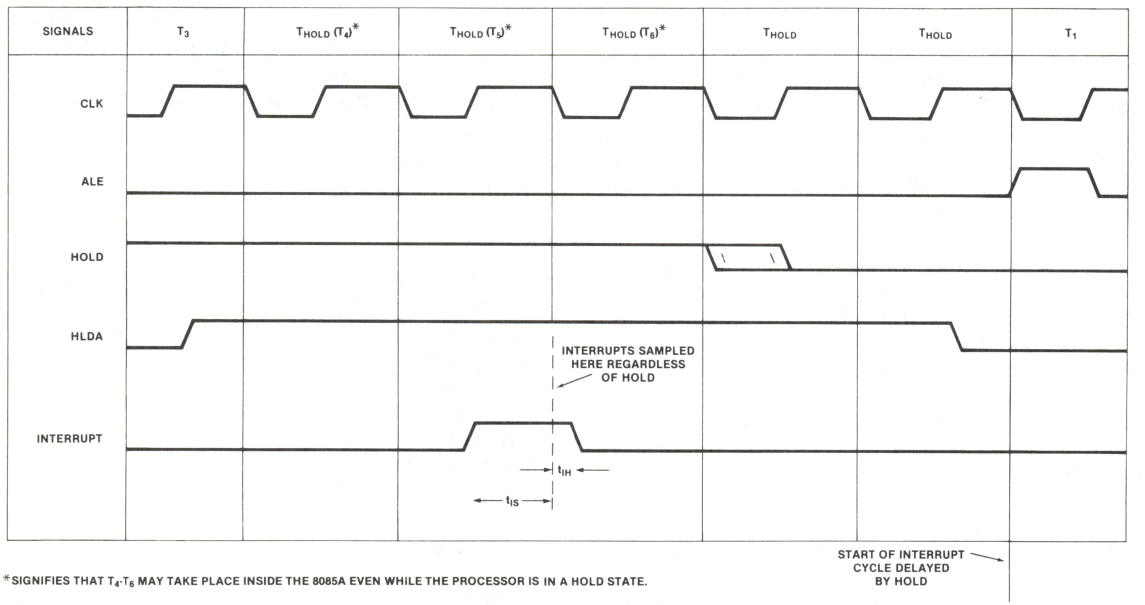


FIGURE 2-21 HOLD VS INTERRUPT — NON HALT

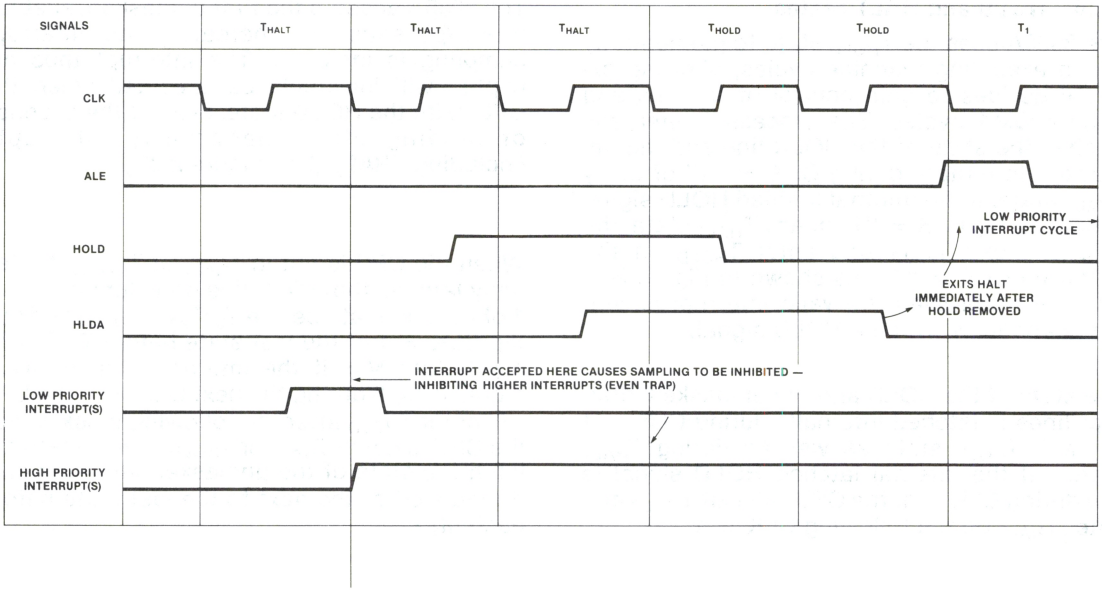


FIGURE 2-22 8085A HOLD VS INTERRUPTS — HALT MODE

2.3.7 Power On and $\overline{\text{RESET IN}}$

The 8085A employs a special internal circuit to increase its speed. This circuit, which is called a substrate bias generator, creates a negative voltage which is used to negatively bias the substrate. The circuit employs an oscillator and a charge pump which require a certain amount of time after POWER ON to stabilize. (See Figure 2-23.)

Taking this circuit into account, the 8085A is not guaranteed to work until 10 ms after V_{CC} reaches 4.75V. For this reason, it is suggested that $\overline{\text{RESET IN}}$ be kept low during this period. Note that the 10 ms period does not include the time it takes for the power supply to reach its 4.75V level — which may be milliseconds in some systems. A simple RC network (Figure 3-6) can satisfy this requirement.

The $\overline{\text{RESET IN}}$ line is latched every CLK = 1. This latched signal is recognized by the CPU during CLK = 1 of the next T state. (See Figure 2-24.) If it is low, the CPU will issue RESET OUT and enter T_{HALT} for the next T state. $\overline{\text{RESET IN}}$ should be kept low for a minimum of three clock periods to ensure proper synchronization of the CPU. When the $\overline{\text{RESET IN}}$ signal goes high, the CPU will enter $M_1 \cdot T_1$ for the next T state. Note that the various signals and buses are floated in T_{RESET} as well as T_{HALT} and T_{HOLD}. For this reason, it is desirable to provide pull-up resistors for the main control signals (particularly $\overline{\text{WR}}$).

Specifically, the $\overline{\text{RESET IN}}$ signal causes the following actions:

RESETS	SETS
PROGRAM COUNTER	RST 5.5 MASK
INSTRUCTION REGISTER	RST 6.5 MASK
INTE FF	RST 7.5 MASK
RST 7.5 FF	
TRAP FF	
SOD FF	
MACHINE STATE FF's	
MACHINE CYCLE FF's	
INTERNALLY LATCHED FF's for HOLD, INTR, and READY	

$\overline{\text{RESET IN}}$ does not explicitly change the contents of the 8085A registers (A, B, C, D, E, H, L) and the condition flags, but due to $\overline{\text{RESET IN}}$ occurring at a random time during instruction execution, the results are indeterminate.

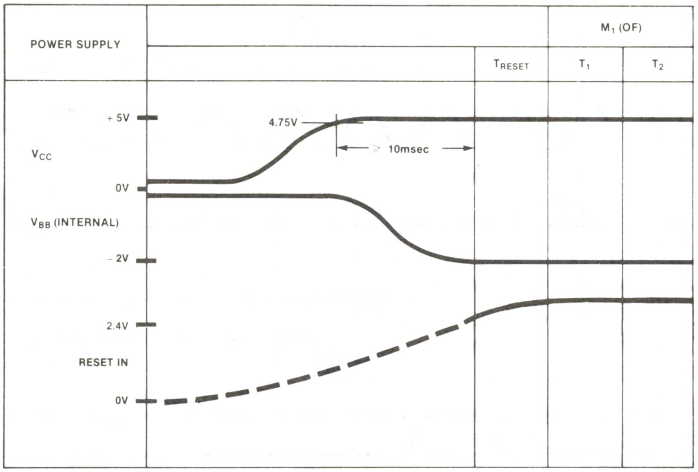


FIGURE 2-23 POWER-ON TIMING

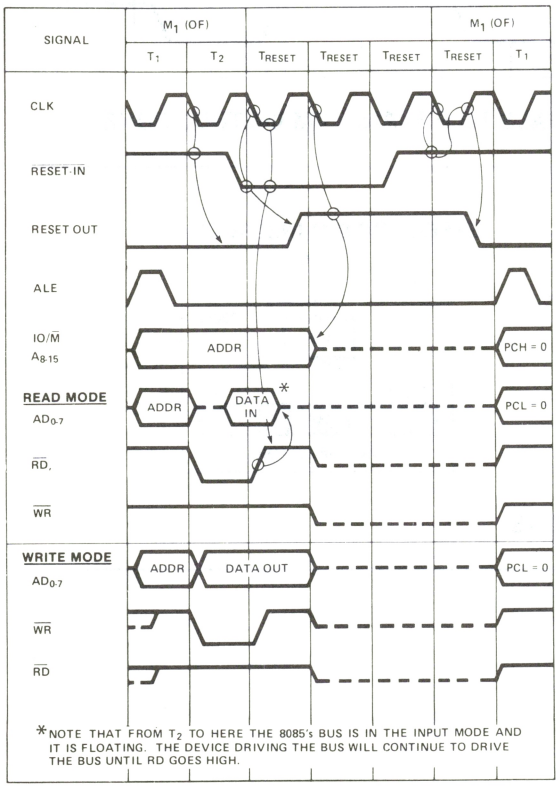


FIGURE 2-24 $\overline{\text{RESET IN}}$ TIMING

Following RESET, the 8085A will start executing instructions at location 0 with the interrupt system disabled, as shown in Figure 2-24.

Figure 2-24 also shows READ and WRITE operations being terminated by a RESET signal. Note that a RESET may prematurely terminate any READ or WRITE operation in process when the RESET occurs.

2.3.8 SID and SOD Signals:

Figure 2-25 shows the timing relationship of the SID and SOD signals to the RIM and SIM instructions. The 8085A has the ability to read the SID line into the accumulator bit 7 using RIM instructions. The state of the SID line is latched internally during $T_3 \cdot CLK = 0$ of the RIM instruction. Following this, the state of the interrupt pins and masks are also transferred directly to the accumulator.

The 8085A can set the SOD flip-flop from bit 7 of the accumulator using the SIM instruction. (See Figure 2-26.) The data is transferred from the accumulator bit 7 to SOD during $M_1 \cdot T_2 \cdot CLK = 0$ of the instruction following SIM, assuming that accumulator bit 6 is a 1. Accumulator bit 6 is a "serial output enable" bit.

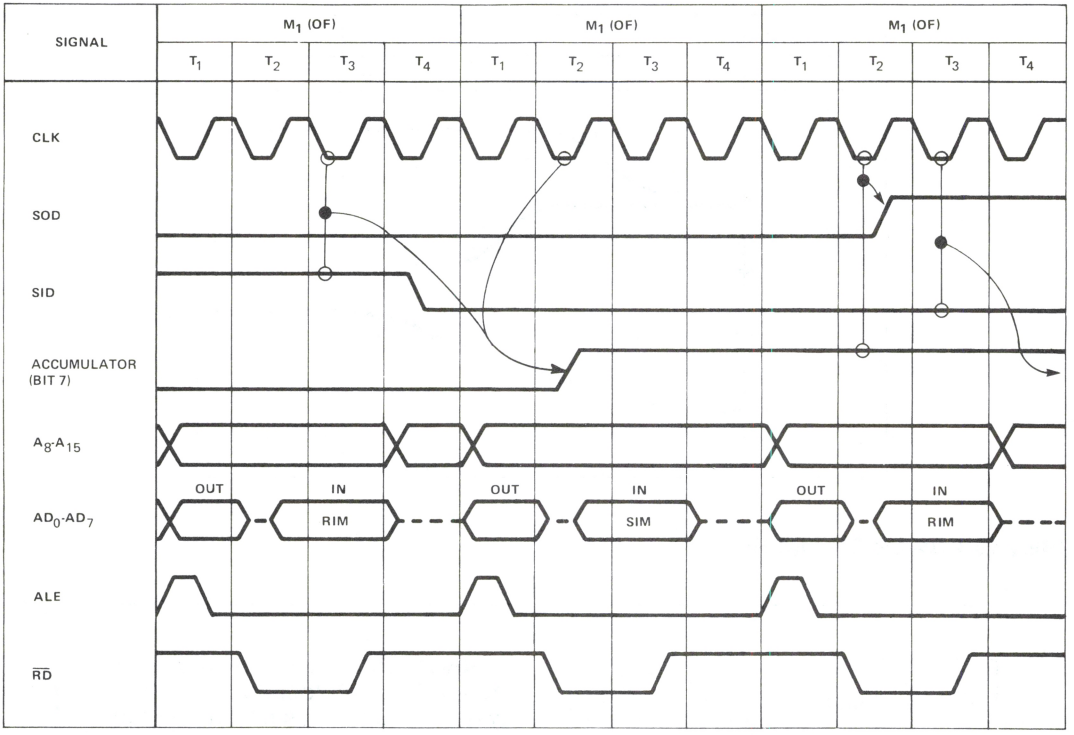


FIGURE 2-25 RELATIONSHIP OF SID AND SOD SIGNALS TO RIM AND SIM INSTRUCTIONS



FIGURE 2-26 EFFECT OF RIM AND SIM INSTRUCTIONS

2.4 COMPARISON OF MCS-80 AND MCS-85 SYSTEM BUSES

This section compares the MCS-80 bus with the MCS-85 bus. Figure 2-28 details the signals and general timing of the two buses; the timing diagrams are drawn to the same scale (8080A clock cycle = 480 ns and 8085A clock cycle = 320 ns) to facilitate comparison.

MCS-80™ System Bus

The MCS-80 bus is terminated on one end by the CPU-GROUP (consisting of the 8080A, 8224, 8228) and on the other end by the various memory and I/O circuits. The following figure shows the major signals of the MCS-80 bus.

MCS-85™ System Bus

The MCS-85 bus is terminated on one end by the 8085A and the other end by various memory and I/O devices. The MCS-85 bus may be optionally de-multiplexed with an 8212 eight bit latch to provide an MCS-80 type bus. The following figure shows the major signals of the MCS-85 bus.

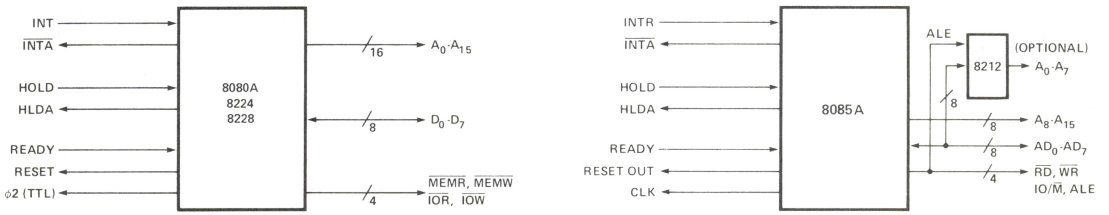


FIGURE 2-27 COMPARISON OF SYSTEM BUSES

MCS-80™ System Bus

SIGNAL(S)	FUNCTION
A_0-A_{15}	The 16 lines of the address bus identify a memory or I/O location for a data transfer operation.
D_0-D_7	The 8 lines of the data bus are used for the parallel transfer of data between two devices.
$\overline{MEMR}$, $\overline{MEMW}$, $\overline{IOR}$, $\overline{IOW}$, $\overline{INTA}$	These five control lines (MEMORY READ, MEMORY WRITE, I/O READ, I/O WRITE, and INTERRUPT ACKNOWLEDGE) identify the type and timing of a data transfer operation.
READY, RESET, HOLD, HLDA φ2 (TTL), INT	These signals are used for the synchronization of slow speed memories, system reset, DMA, sytem timing, and CPU interrupt.

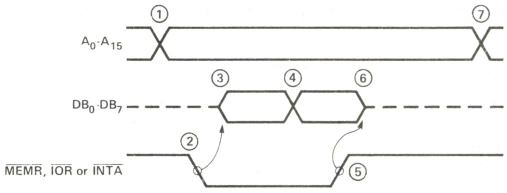
MCS-85™ System Bus

SIGNAL(S)	FUNCTION
A_8-A_{15}	These are the high order eight bits of the address, and are used to identify a memory or I/O location for a data transfer cycle.
AD_0-AD_7	These eight lines serve a dual function. During the beginning of a data transfer operation, these lines carry the low order eight bits of the address bus. During the remainder of the cycle, these lines are used for the parallel transfer of data between two devices.
$\overline{RD}$, $\overline{WR}$, $\overline{INTA}$	These signals identify the type and timing of a data transfer cycle.
IO/$\overline{M}$	The I/O/$\overline{MEMORY}$ line identifies a data transfer as being in the I/O address space or the memory address space.
ALE	ADDRESS LATCH ENABLE enables the latching of the A_0-A_7 signals.
READY, RESET OUT, HOLD, HLDA, CLK, INTR	These signals are used for the synchronization of slow speed memories, system reset, DMA, system timing and CPU interrupt.

FIGURE 2-28 COMPARISON OF SYSTEM BUSES

MCS-80™ System Bus for READ CYCLE

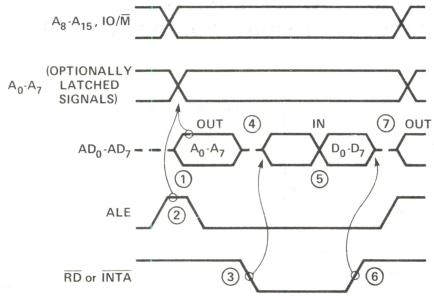
The basic timing of the MCS-80 BUS for a READ CYCLE is as follows:



The MCS-80 first presents the address (1) and shortly thereafter the control signal (2). The data bus, which was in the high impedance state, is driven by the selected device (3). The selected device eventually presents the valid data to the processor (4). The processor raises the control signal (5), which causes the selected device to put the data bus in the high impedance state (6). The processor then changes the address (7) for the start of the next data transfer.

MCS-85™ System Bus for READ CYCLE

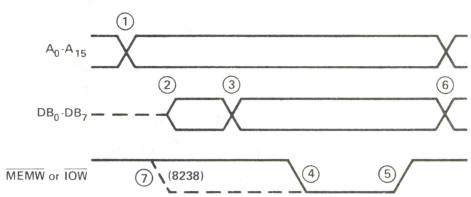
The basic timing of the MCS-85 BUS for a READ CYCLE is as follows:



At the beginning of the READ cycle, the 8085A sends out all 16 bits of address (1). This is followed by ALE (2) which causes the lower eight bits of address to be latched in either the 8155/56, 8355, 8755A, or in an external 8212. $\overline{RD}$ is then dropped (3) by the 8085A. The data bus is then tri-stated by the 8085A in preparation for the selected device driving the bus (4); the selected device will continue to drive the bus with valid data (5), until $\overline{RD}$ is raised (6) by the 8085A. At the end of the READ CYCLE (7), the address and data lines are changed in preparation for the next cycle.

MCS-80™ System Bus for WRITE CYCLE

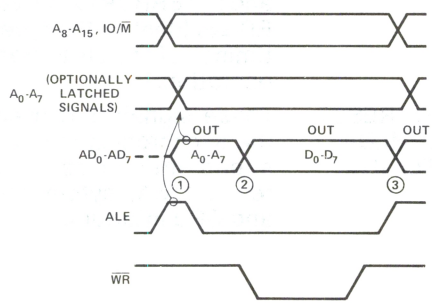
The basic timing of the MCS-80 BUS for a WRITE CYCLE is as follows:



The MCS-80 first presents the address (1), then enables the data bus driver (2), and later presents the data (3). Shortly thereafter, the MCS-80 drops the control signal (4) for an interval of time and then raises the signal (5). The MCS-80 then changes the address (6) in preparation for the next data transfer. The advance write signal of the 8238 is also shown (7).

MCS-85™ System Bus for WRITE CYCLE

The basic timing of the MCS-85 BUS for a WRITE CYCLE is as follows:



The timing of the WRITE CYCLE is identical to the MCS-85 READ CYCLE with the exception of the AD_0-AD_7 lines. At the beginning of the cycle (1), the low order eight bits of address are on AD_0-AD_7. After ALE drops, the eight bits of data (2) are put on AD_0-AD_7. They are removed (3) at the end of the WRITE CYCLE, in anticipation of the next data transfer.

FIGURE 2-28 (Continued) COMPARISON OF SYSTEM BUSES

The following observations of the two buses can be made:

1. The access times from address leaving the processor to returning data are almost identical, even though the 8085A is operating 50% faster than the 8080.
2. With the addition of an 8212 latch to the 8085A, the basic timings of the two systems are very similar.
3. The 8085A has more time for address setup to $\overline{RD}$ than the 8080.
4. The MCS-80 has a wider $\overline{RD}$ signal, but a narrower $\overline{WR}$ signal than the 8085A.
5. The MCS-80 provides stable data setup to the leading and trailing edges of $\overline{WR}$, while the 8085 provides stable data setup to only the trailing edge of $\overline{WR}$.
6. The MCS-80 control signals have different widths and occur at different points in the machine cycle, while the 8085A control signals have identical timing.
7. While not shown on the chart, the MCS-80 data and address hold times are adversely affected by the processor preparing to enter the HOLD state. The 8085A has identical timing regardless of entering HOLD.
8. Also not shown on the chart is the fact that all output signals of the 8085A have $-400\mu a$ of source current and 2.0 ma of sink current. The 8085A also has input voltage levels of $V_{IL} = 0.8V$ and $V_{IH} = 2.0V$.

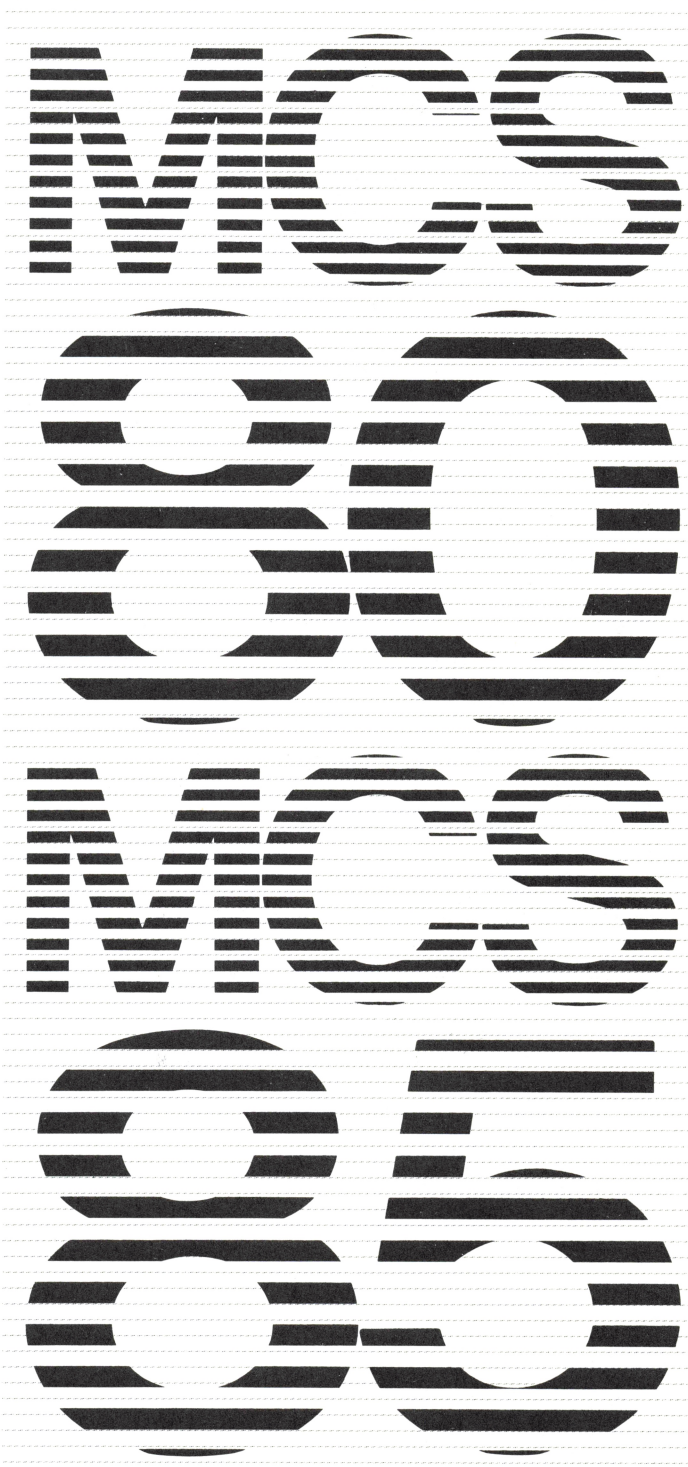
CONCLUSION:

The preceding discussion has clearly shown that the MCS-85 bus satisfies the two restrictions of COMPATIBILITY and SPEED. It is compatible because it requires only an 8212 latch to generate an MCS-80 type bus. If the four control signals $\overline{MEMR}$, $\overline{MEMW}$, $\overline{IOR}$ and $\overline{IOW}$ are desired, they can be generated from $\overline{RD}$, $\overline{WR}$, and IO/$\overline{M}$ with a decoder or a few gates. The MCS-85 bus is also fast. While running at 3MHz, the 8085A generates better timing signals than the MCS-80 does at 2MHz. Furthermore, the multiplexed bus structure doesn't slow the 8085A down, because it is using the internal states to overlap the fetch and execution portions of different machine cycles. Finally, the MCS-85 can be slowed down or sped up considerably, while still providing reasonable timing.

TO USE. The $\overline{RD}$, $\overline{WR}$, and $\overline{INTA}$ control signals all have identical timing, which isn't affected by the CPU preparing to enter the HOLD state. Furthermore, the address and data bus have good setup and hold times relative to the control signals. The voltage and current levels for the interface signals will all drive buses of up to 40 MOS devices, or 1 schottky TTL device.

The MCS-85 system bus is also EFFICIENT. Efficiency is the reason that the lower eight address lines are multiplexed with the data bus. Every chip that needs to use both A_0-A_7 and D_0-D_7 saves 7 pins (the eighth pin is used for ALE) on the interface to the processor. That means that 7 more pins per part are available to either add features to the part or to use a smaller package in some cases. In the three chip system shown in Figure 3-6, the use of the MCS-85 bus saves 3 x 7 = 21 pins, which are used for extra I/O and interrupt lines. A further advantage of the MCS-85 bus is apparent in Figure 3-7, which shows a printed circuit layout of the circuit in Figure 3-6. The reduced number of pins and the fact that compatible pinouts were used, provides for an extremely compact, simple, and efficient printed circuit. Notice that great care was taken when the pinouts were assigned to ensure that the signals would flow easily from chip to chip to chip.

Chapter 3
8085A System Operation and Interfacing



CHAPTER 3
8085A SYSTEM OPERATION AND INTERFACING

3.1 INTERFACING TO THE 8085A

The 8085A interfaces to both memory and I/O devices by means of READ and WRITE machine cycles, the timing of which are identical. During each machine cycle the 8085A issues an address and a control signal, then either sends data out on the bus or reads data from the bus. The 8085A may be performing a READ machine cycle, but what it reads could be a ROM, RAM, I/O device, peripheral device, or nothing.

There is no distinction between data, instruction opcodes, and I/O port numbers except the way the CPU interprets what it reads from the bus. If an opcode is what would logically appear on the bus, the CPU will treat as an opcode whatever does appear there; if an I/O port number is to be expected, what appears will be interpreted as a port number. The same is true for a WRITE cycle. The 8085A issues an address, data, and a control signal. Unless it is requested to WAIT (by use of the READY line) it will complete the cycle and proceed to the next. Regardless of whether there is a device present to accept the data, the CPU executes one instruction at a time, in sequence, until told to do otherwise. The program controls the sequence and nature of all machine cycles until an interrupt occurs.

There are two ways of addressing I/O devices in the MCS-85 system. If the IO/$\overline{M}$ output from the CPU is used to distinguish between I/O and memory READ and WRITE cycles, then that system is said to employ standard, or I/O-mapped, I/O. If IO/$\overline{M}$ is not so used, the CPU does not distinguish between I/O and memory, and its system employs memory-mapped I/O. Each method of addressing I/O has advantages and disadvantages.

3.2 MEMORY-MAPPED I/O

3.2.1 Advantages of Memory-Mapped I/O

Since the processor doesn't distinguish I/O from memory using this addressing scheme, you can take advantage of the larger instruction set that references the memory address space. Instead of only being able to transfer a byte of data between the accumulator and the I/O port (using INPUT and OUTPUT instructions), you can now program arithmetic and logic operations on port data as well as move data between any internal register and the I/O port. Consider the new meaning of the following instructions:

Examples:

MOVr,M	(Input Port to any Register)
MOV M,r	(Output any Register to Port)
MVI M	(Output immediate data to Port)
LDA	(Input Port to ACC)
STA	(Output from ACC to Port)
LHLD	(16-Bit Input)
SHLD	(16-Bit Output)
ADD M	(Add Port to ACC)
ANA M	(AND Port with ACC)

3.2.2 Disadvantages of Memory-Mapped I/O

While memory instructions may increase the flexibility of the I/O system, there are some drawbacks. Since I/O devices are now addressed as memory, there are fewer addresses available for memory. A common practice is to use address bit 15 (A_{15}) to distinguish memory from I/O. (See Figure 3-2 and accompanying discussion.) If $A_{15} = 0$ then memory is being addressed; if $A_{15} = 1$, I/O is being addressed. This particular scheme limits the maximum amount of memory that can be used to 32k bytes. A further disadvantage of memory-mapped I/O is that it takes 3 bytes of instruction and 13 clock cycles using the LDA or STA instructions to specify moving a byte of data between the accumulator and an I/O device, whereas the INPUT and OUTPUT instructions require only two bytes and 10 clock cycles. This is because the I/O address space is smaller (only 256 bytes) and therefore requires fewer bits to completely specify an address. A futher advantage of using the INPUT and OUTPUT Instructions is that it allows the easy connection of the MCS-80 peripherals to the MCS-85 multiplexed bus. If you memory-map the MCS-80 peripherals to the MCS-85 bus, you must either latch the lower address bits with an 8212 or use a portion of the memory address space by connecting the chip selects and address lines of the ports to the unmultiplexed upper eight lines of the address bus.

3.3 ADDRESS ASSIGNMENT

3.3.1 Decoding

Besides memory-mapped I/O, another practice is to only partially decode the address bus when generating chip selects. Every device has a given number of unique addresses associated with it. The 8355, for instance, has 2k bytes of ROM and therefore has 2k addresses associated with the ROM. Any one of these 2k addresses can be uniquely specified by a pattern on the 11 ($2^{11} = 2k$) address lines. However, since the 8355 must work with other devices in a system, it isn't enough to simply specify the 11 bits; further bits of information must be used to locate the 2k bytes within the 65k address space. The 2k bytes are located by the use of chip enable (CE) inputs to the 8355 chip. If the 8355 were to occupy the first 2k bytes of the memory address space, it would, strictly speaking, be necessary to decode the fact that A_{15}-A_{11} were all zeroes, and use that condition as a chip enable. Then the 8355 would be selected only when the address bus was less than 2k.

However, if other 2k blocks of addresses aren't being used, you may combine those addresses and not decode all of the upper five address lines for chip enables. In fact, in a small system you may need to decode only one bit of address, which is to say connect that bit of the address bus to the chip enable line of the 8355. If you connect A_{11} to the $\overline{CE}$ line of the 8355 and tie CE to V_{CC}, then the 8355 would be selected whenever the memory address was less than 2k. (See Figure 3-1A.)

However, it will also be selected whenever memory locations 4k-6k, 8k-10k, 61k-63k (i.e., whenever bit $A_{11} = 0$) is addressed. If the programmer is aware of this, and if there are no other devices assigned to the other address spaces, then it may be an acceptable condition. Care must be taken, however, to ensure that at no time will two different devices be selected simultaneously. Whenever one device is selected, that memory address must deselect all other devices. If two devices are selected simultaneously for a READ operation, the electrical conflict on the bus may damage one or both parts. Note also that the address bus may reflect an undesired address during T_5, T_6 of an opcode fetch cycle and during address bus transitional periods in T_1 (this is illustrated in Chapter 2). Therefore, all memory and I/O devices must qualify their selection with $\overline{RD}$ or $\overline{WR}$, or the address on the bus at the falling edge of the ALE, so as to ignore all spurious addresses.

3.3.2 Linear Selection

Using an address bit as a chip select is referred to as linear selection. The direct consequence of linear selection is that you cut the available address space in half for each single address bit used as a chip enable. If this penalty is too high, you can always use an 8205 one-of-eight decoder. Also, some chips have multiple chip enables, which allows for some automatic decoding of the address. (See Figures 3-1B and 3-1C.)

One drawback to linear selection is that the memory addresses of the different parts are not contiguous. For example, if three 8355s are addressed using linear selection, one might be located at 0-2k, the next at 6k-8k, and the next at 10k-12k. The programmer must recognize these page boundries and jump over them.

3.4 INTERFACING TO THE 8155/8156, 8355/8755A

3.4.1 I/O Mapped I/O:

This section describes some of the techniques involved in connecting the MCS-85 combination memory and I/O chips to the 8085A as I/O devices.

Figure 3.1A shows one 8355 connected to the 8085A bus. (In the interest of simplicity, only the chip enable and IO/$\overline{M}$ lines are shown; the other lines are connected as shown in Figures 3.6, 3.7 or 3.8.) Notice that CE is tied to V_{CC} and $\overline{CE}$ is connected to A_{11}. This is because after RESET the processor always starts executing at location 0. Since the ROM normally contains the program, it must be selected when the address is all zeroes.

One consequence of the ROM being selected by an all-zero address is that the I/O ports on the chip will be selected only when $A_{11} = 0$. This is because the I/O ports and the memory have common chip enables, therefore forcing the selection conditions of one onto the other. Furthermore, since the IO/$\overline{M}$ line of the chip is connected to the IO/$\overline{M}$ line of the 8085A, the port has I/O mapped I/O. The I/O ports can be accessed only by use of the INPUT and OUTPUT instructions; since these are the only instructions that cause IO/$\overline{M}$ to go high.

The boxes to the right of the chip in Figure 3.1A indicate the memory addresses and I/O Port numbers required to access the chip. As a result of the linear selection technique used, there are many "don't care" bits (marked by "X"s) in the address. While they don't affect the addressing of this device, they may affect other

FIGURE 3-1A SINGLE CHIP

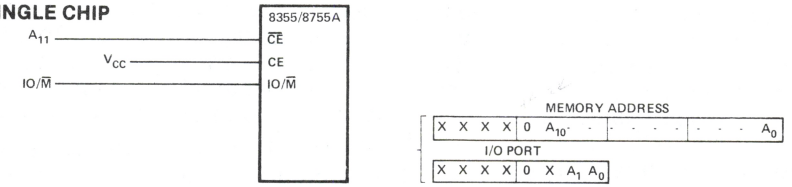


FIGURE 3-1B MULTIPLE CHIPS

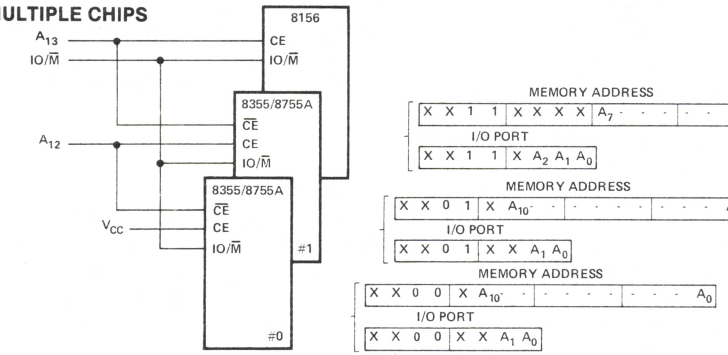


FIGURE 3-1C FULLY DECODED AND EXPANDED

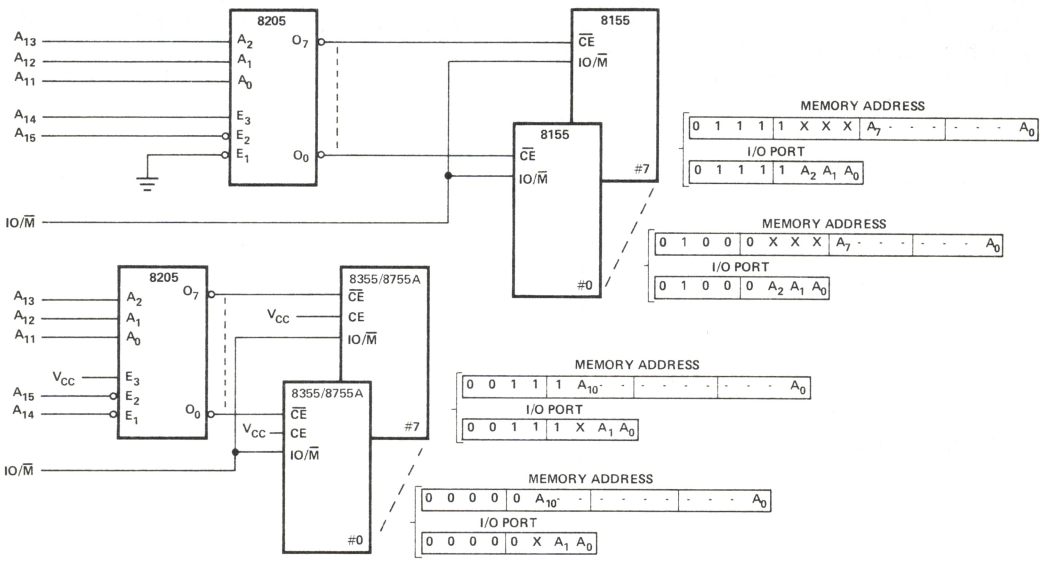


FIGURE 3-1D SEPARATE CHIP ENABLES FOR I/O AND MEMORY

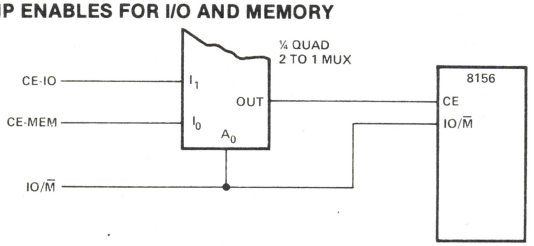


FIGURE 3-1 MCS-85™ PERIPHERALS WITH I/O MAPPED I/O

devices in the system, which would force them to be either ones or zeroes. Remember that two devices may not be selected simultaneously; thus each device must have an address that not only selects itself, but also deselects all other devices. If there are any bits which are truly "don't cares," they are customarily assigned to be zero. If all the "X" bits in Figure 3.1A were "don't cares," then the chip could be addressed as memory locations 0-2k, and I/O Ports 0-3.

Figure 3.1B shows a slightly larger system of two 8355s and one 8156. Notice that 8355 No. 1 uses its two chip enable lines to decode $A_{12} = 1$, $A_{13} = 0$. It is possible to address each of the chips without selecting any of the others. Also notice that there are some illegal addresses (e.g., $A_{12} = 0$, $A_{13} = 1$) that would cause two of the devices to turn on simultaneously. The programmer must not use these addresses.

Figure 3.1C shows a larger MCS-85 system. Two 8205s are used to completely decode the addresses. There are some interesting points to observe here. First, while some of the devices have multiple possible address (i.e., they have some "don't care" bits), there aren't any addresses which can cause simultaneous selection of two or more parts. Second, the I/O and memory portions of the 8x55 components share chip enables, so they are forced to live with each other's constraints. Third, only one 8205 is required per eight chips for the decoding; that's an overhead of only 1/8 of a chip per part.

Figure 3.1D shows a remedy to the problem illustrated in Figure 3.1C, namely that I/O and memory portions of the chip are forced to live with each other's chip enable constraints. By using a quad 2 to 1 multiplexer, the chip enables of the I/O and memory portions of four chips can be independently assigned.

3.4.2 Memory-Mapped I/O:

Figure 3.2A shows an 8355 connected to the 8085A. Since the IO/$\overline{M}$ pin of the 8355 is connected to A_{15}, whenever $A_{15} = 1$ the I/O ports will be accessed. While A_{15} could be set to 1 either by a memory or by an I/O instruction, in this situation the port is usually accessed only by the memory instructions. You may access ports either as memory locations (where $A_{15} = 1$ refers to a memory address of 32k or higher) or as I/O ports (where $A_{15} = 1$ refers to an I/O address of 128 or higher, since bits A_8-A_{15} are a

FIGURE 3-2A SINGLE CHIP

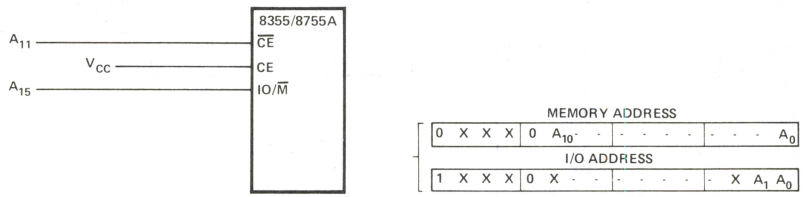


FIGURE 3-2B MULTIPLE CHIPS

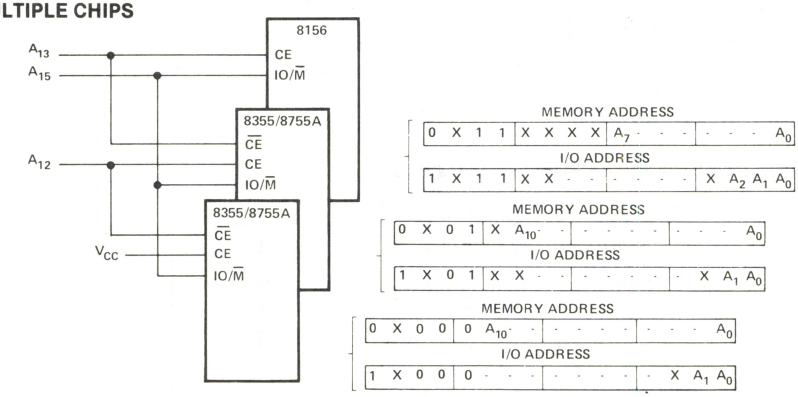


FIGURE 3-2 MCS-85™ PERIPHERALS WITH MEMORY-MAPPED I/O

replication of bits A_0-A_7). Assuming that memory-mapped I/O is used, the addresses are shown in the boxes to the right in Figure 3-2. If you want to be sure that neither the I/O nor the memory is ever selected by any INPUT or OUTPUT instruction, then the chip enable must be conditioned by IO/$\overline{M}$ = 0.

Figure 3.2B shows a somewhat larger system, also using memory-mapped I/O. As in Figure 3.1B care must be exercised to ensure that no two devices are accessed simultaneously. You can see that considerable memory address space is used up as a result of using memory-mapped I/O.

3.5 INTERFACING TO MCS-80™ PERIPHERALS

3.5.1 I/O Mapped I/O:

For want of a better name, the Intel® 825x, 827x, and 829x series peripherals are referred to here as MCS-80 peripherals because unlike the 8155/56, 8355 and 8755A, they are compatible with the nonmultiplexed MCS-80 system bus.

To interface to an MCS-80 peripheral, you must provide a constant address, a chip select, and $\overline{RD}$ or $\overline{WR}$. Since the upper address lines (A_8-A_{15}) of the 8085A are nonmultiplexed, they can be tied directly to the peripherals, as shown in Figure 3.3A. To provide I/O mapped I/O, use either linear selection (keeping the I/O and memory addresses noncoincidental), or condition the chip selects $\overline{WR}$ with IO/$\overline{M}$ = 1. Figure 3.3A shows a technique of gating the chip selects with IO/$\overline{M}$ = 1, using an 8205. This technique also allows more I/O devices to be used than linear selection would. Note that this technique relies on the fact that the I/O Port number is copied onto A_8-A_{15} as well as A_0-A_7 during an INPUT or OUTPUT instruction.

Figure 3.3B shows an alternative approach to interfacing to MCS-80 components. By latching the lower 8 bits of address with an 8212, and decoding the control signals with an 8205, you create an exact copy of the MCS-80 (8080A, 8224, 8228) bus. You may then use whatever circuits have been previously developed for the 8080. The total cost is one 8212 and one 8205. Since the same signals might have needed buffering anyway (and the 8212 and 8205 provide buffering of their outputs), the extra component overhead ranges from little to nothing.

3.5.2 Memory-Mapped I/O:

Exactly the same techniques used to memory map the MCS-85 apply to the MCS-80 I/O devices. Figure 3.4 shows an 8205 used to qualify the chip select of the I/O device with IO/$\overline{M}$ = 0. Since the MCS-80 peripherals require nonmultiplexed address lines, linear select is not too useful unless the address lines are latched. This is because connecting both the chip selects and the address lines of the MCS-80 peripherals to A_8-A_{15} would deplete all the useful addresses very quickly.

3.6 INTERFACING TO STANDARD BUS MEMORIES

Standard bus memory devices are designed to be used with nonmultiplexed address and data buses. Interfacing to standard memories is very similar to interfacing to MCS-85 memories with the exception that A_0-A_7 must be latched. Once this requirement is met, all the tricks discussed earlier can be used. Since the address lines would eventually require buffering as the system size grew, the overhead of the 8212 latch again becomes negligible.

Figure 3.5 shows the interface of the 8085A to a large block of memory, specifically 16k bytes of ROM and 8k bytes of RAM. Besides the memories, the circuit requires only 2-1/6 other parts for logical gating. If MCS-80 I/O parts were used, the 8212 latch could be shared between the two groups, further reducing the gating overhead per IC. Sixteen 2142 chips and eight 2316E chips are used in this design. The data bus, address lines 8-10, and control signals in this system all should be buffered. This applies to any system with the number of memory devices represented here.

Wherever two or more parts are paralleled on the same bus, they must be 3-state devices such as the 2142 RAM, 2316E ROM, 2716 EPROM, 2332 ROM, 2732 EPROM, and 2364 ROM, which have either an output disable (OD) input or multiple chip select (CS) inputs. To prevent bus contention, only one memory device may be output-enabled at a time in this configuration; the outputs of all others must be deselected during $\overline{RD}$.

For additional information on interfacing standard memory devices, please read Section 2 of Appendix I and the Intel applications note AP-30 "Application of Intel's 5V EPROM and ROM Family for Microprocessor Systems" available from: Intel, Literature Dept., 3065 Bowers Ave., Santa Clara, CA 95051.

3.7 DYNAMIC RAM INTERFACE:

For interfacing the dynamic RAM, Intel makes a single-component dynamic RAM refresh controller, the 8202, which interfaces the 8085A to multiplexed-address-bus dynamic RAMs like

FIGURE 3-3A DECODED CHIP SELECTS

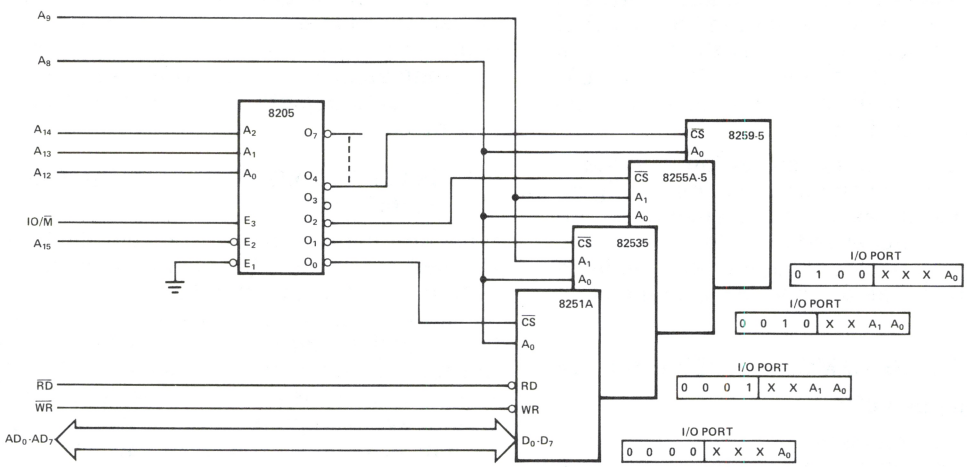


FIGURE 3-3B DECODED CONTROLS AND LATCHED ADDRESS (MCS-80™ TYPE BUS)

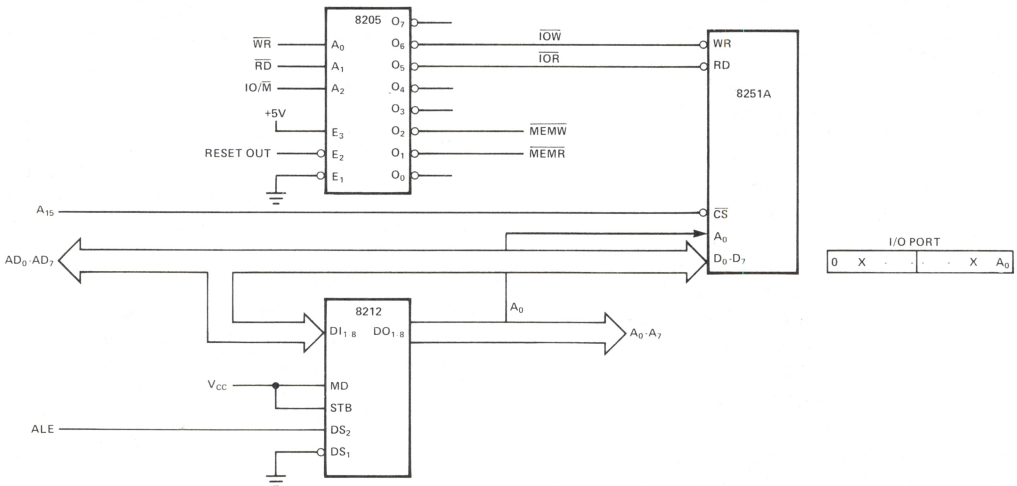


FIGURE 3-3 MCS-80™ PERIPHERALS WITH I/O MAPPED I/O

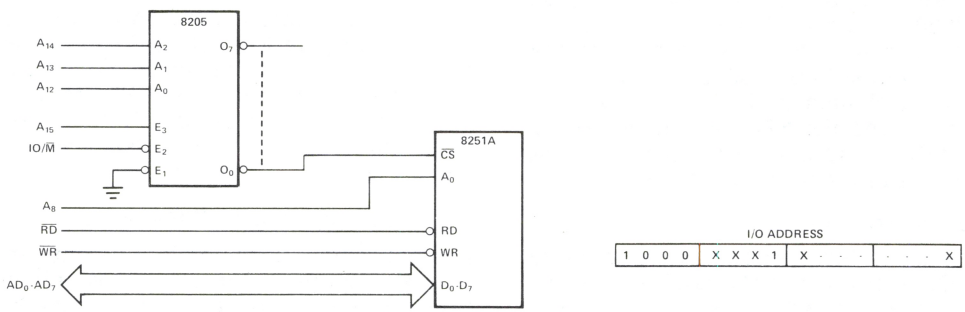


FIGURE 3-4 MCS-80™ PERIPHERALS WITH MEMORY-MAPPED I/O AND DECODED CHIP SELECTS

the Intel 2104A and 2117. The 8202 provides the necessary refreshing for such dynamic RAMs, and also provides the control signals required for accessing, selecting, and address clocking. It allows for the use of the 8085A's full capability of 64k bytes of address space with no additional buffering devices. As with other standard memory interfaces, it is necessary to demultiplex the lower 8 bits of address from the multiplexed 8085A bus, AD_{0-7}.

3.8 MINIMUM MCS-85™ SYSTEM

The Schematics of Figure 3.6 depict a minimum system core. In actual use, some of the processor control signals (TRAP, INTR, and HOLD) would have to be terminated. Also, interface logic to external devices as well as more memory and I/O devices may be desirable. The first thing one notices about the system in Figure 3.6 is the scarcity of parts required to build this system. With a minimum of parts, we have constructed a microcomputer system that has the following functions:

PARTS	FUNCTIONS
1 8085A	1 CPU (Clock cycle ≤320 ns)
1 8355/8755A	2048 Bytes of either EPROM or ROM
1 8156	256 Bytes of RAM
1 Crystal	38 I/O Lines
4 Resistors	5 Interrupts
1 Capacitor	1 Programmable Timer/ Counter
1 Diode	1 Crystal and Oscillator
1 +5 Power Supply	1 Clock
	1 Power-on Reset

By looking at the printed circuit layout of Figure 3.7, we can see that not only are there just 3 ICs, but that the interconnection of these parts is extremely easy and provides a very dense layout. Expecially notice the easy flow of the system bus on the solder side of the board.

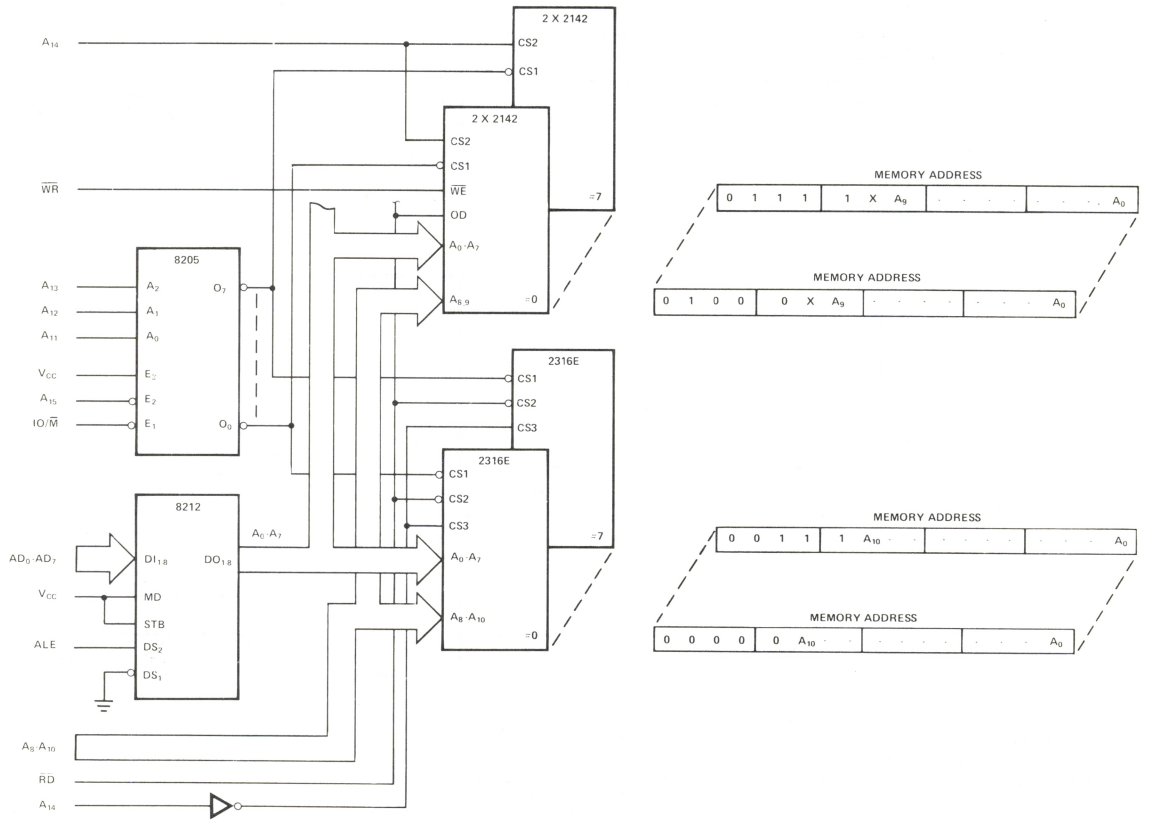
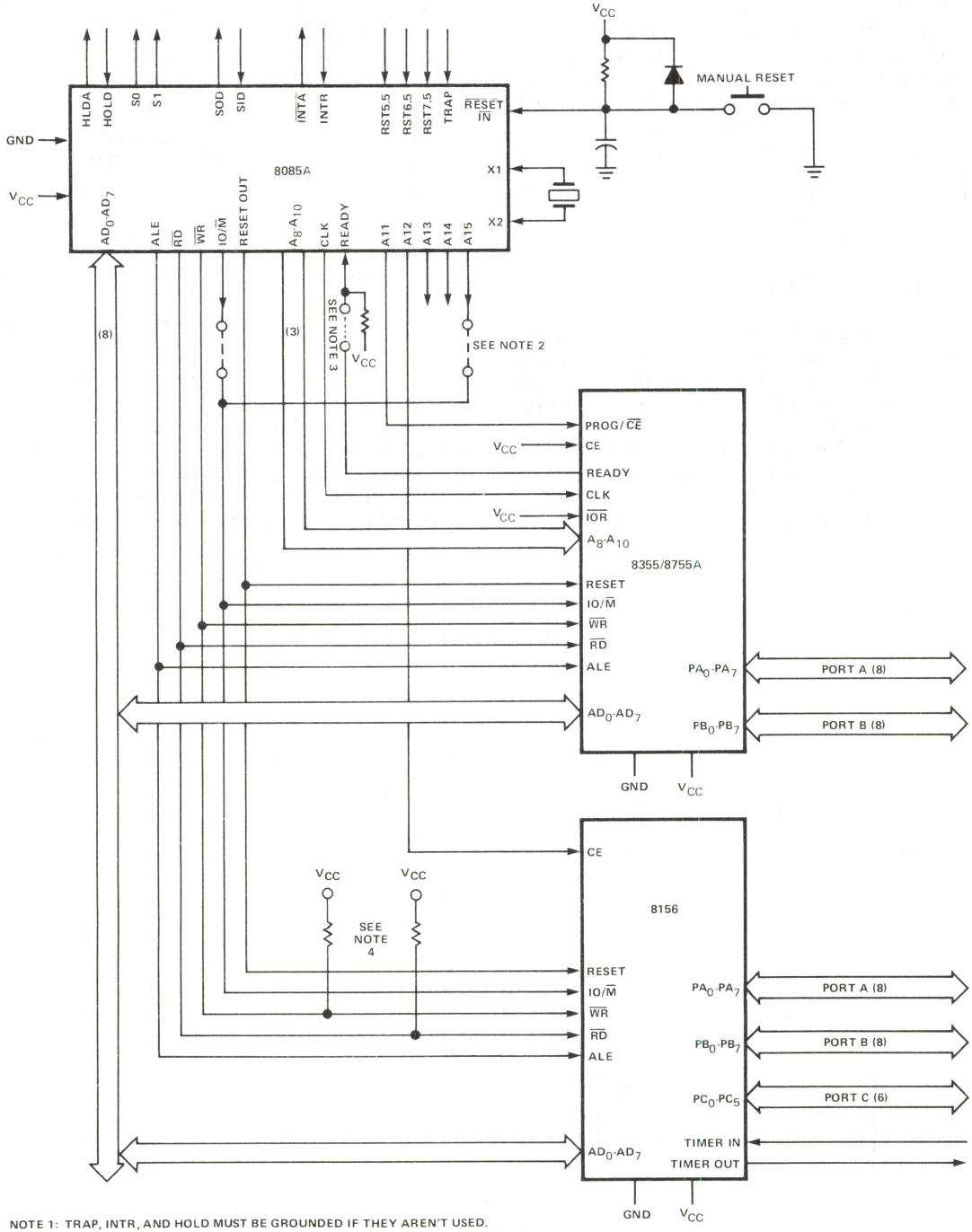
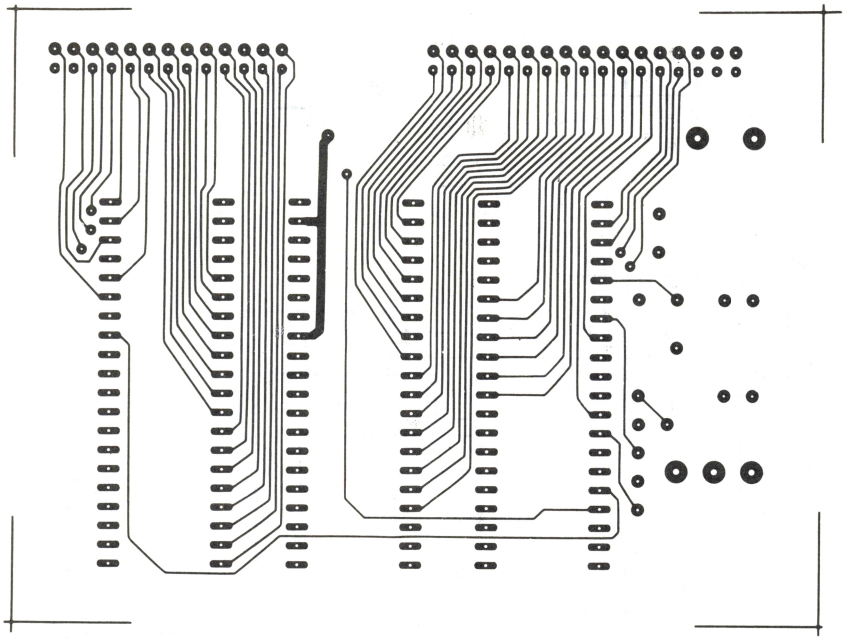


FIGURE 3-5 STANDARD MEMORIES WITH LATCHED ADDRESS AND DECODED CHIP SELECTS

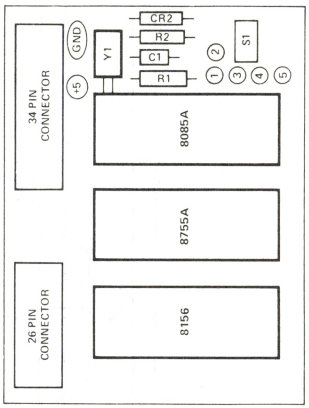


NOTE 1: TRAP, INTR, AND HOLD MUST BE GROUNDED IF THEY AREN'T USED.
NOTE 2: USE IO/M FOR STANDARD I/O MAPPING. USE A15 FOR MEMORY MAPPED I/O.
NOTE 3. CONNECTION IS NECESSARY ONLY IF ONE T_{WAIT} STATE IS DESIRED.
NOTE 4: PULL-UP RESISTORS RECOMMENDED TO AVOID SPURIOUS SELECTION WHEN $\overline{RD}$ AND $\overline{WR}$ ARE 3-STATED. THESE RESISTORS ARE NOT INCLUDED ON THE PC BOARD LAYOUT OF FIGURE 3-7.

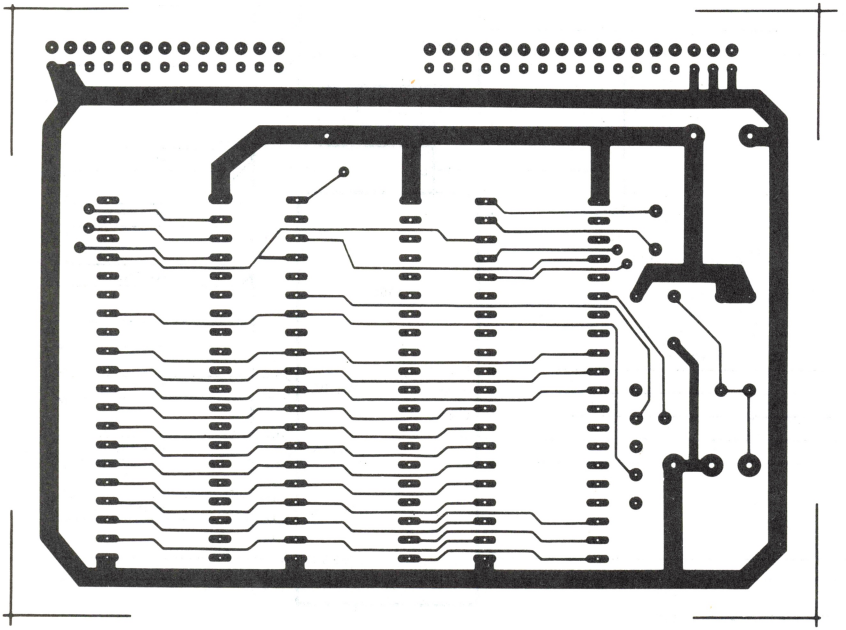
FIGURE 3-6 MINIMUM 8085 SYSTEM



COMPONENT SIDE
SCALE: ≈1:1

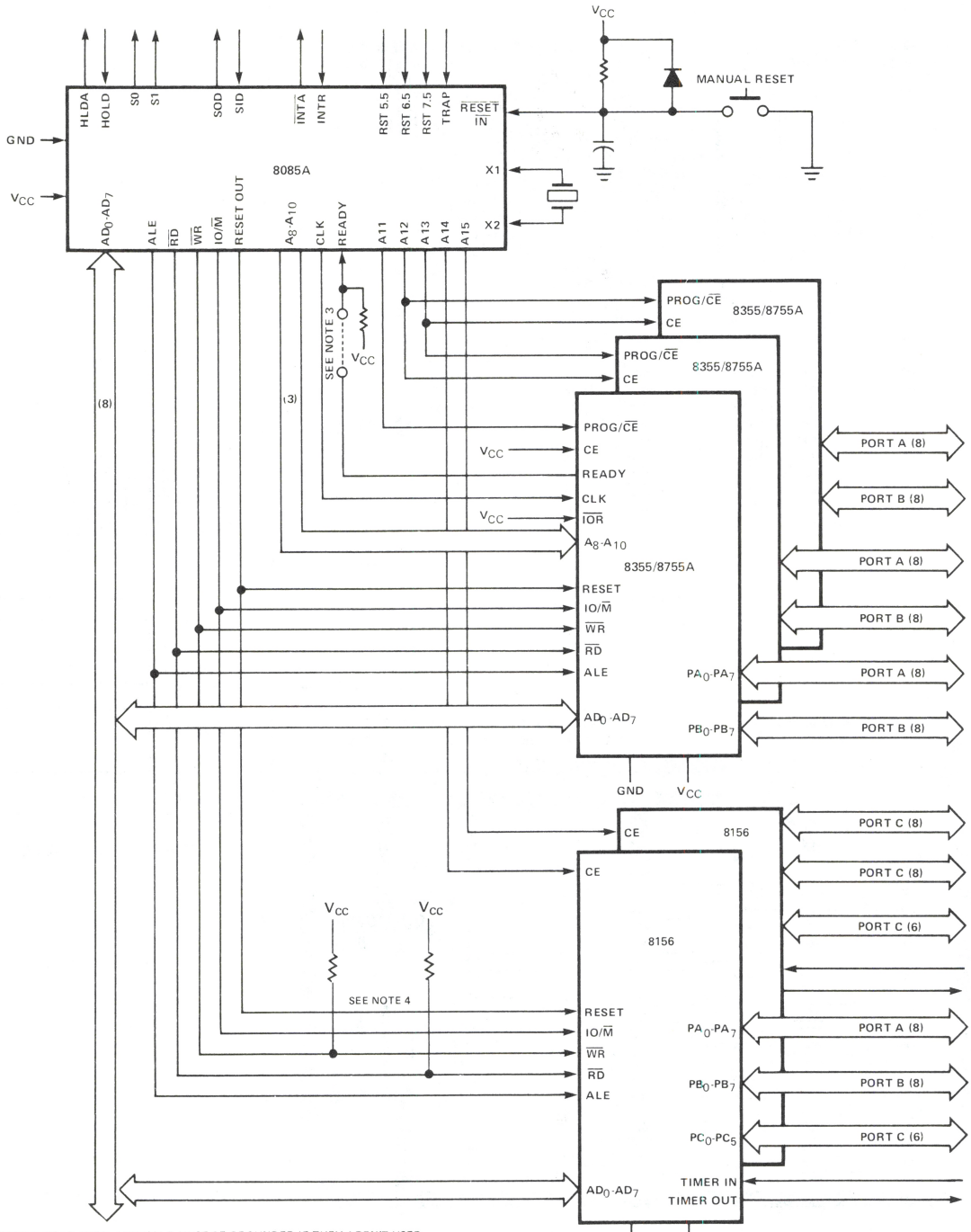


COMPONENT LAYOUT



SOLDER SIDE
SCALE: ≈1:1

FIGURE 3-7 PRINTED CIRCUIT LAYOUT



NOTE 1: TRAP, INTR, AND HOLD MUST BE GROUNDED IF THEY AREN'T USED.
NOTE 2: IN THIS CONFIGURATION, THE I/O CAN'T BE MEMORY MAPPED (WITHOUT EXTRA LOGIC) BECAUSE ALL OF THE ADDRESS LINES ARE IN USE.
NOTE 3: CONNECTION IS NECESSARY ONLY IF ONE T_{WAIT} STATE IS DESIRED.
NOTE 4: PULL-UP RESISTORS RECOMMENDED TO AVOID SPURIOUS SELECTION WHEN $\overline{RD}$ AND $\overline{WR}$ ARE 3-STATED.

FIGURE 3-8 EXPANDED SYSTEM

3.9 EXPANDED MCS-85™ SYSTEM

Figure 3.8 shows the circuit Figure 3.6 expanded to its maximum size without the use of any extra logic. In an extremely small board area we can fit:

PARTS	FUNCTION
1 8085A	1 CPU (Clock cycle
3 8355/8755A	⩽ 320ns)
2 8156	ROM/EPROM
1 Crystal	6144 Bytes
4 Resistors	512 Bytes RAM
1 Capacitor	76 I/O Lines
1 Diode	5 Interrupts
	2 Programmable Timer/Counters
	2 Serial I/O Lines
	1 Crystal and Oscillator
	1 Clock
	1 Power-on Reset

3.10 MCS-85™ SYSTEM WITH 8185

The 8185 1K-byte static RAM chip is another multiplexed-bus component that insures that the most highly integrated systems can be built with MCS-85 components. Figure 3.9 shows a 4-chip MCS-85 system schematic with the following characteristics:

PARTS	FUNCTION
1 8085A	1 CPU
1 8185	ROM/EPROM
1 8156	2048 Bytes
1 8355/8755A	1280 Bytes RAM
	38 I/O Lines
	5 Interrupts
	1 Timer/Counter
	2 Serial I/O Lines

The 8185 also has power-down capability. By connecting $\overline{CE}_1$ to IO/$\overline{M}$ from the 8085A the 8185 will be powered down during I/O operations and Interrupt Acknowledge cycles.

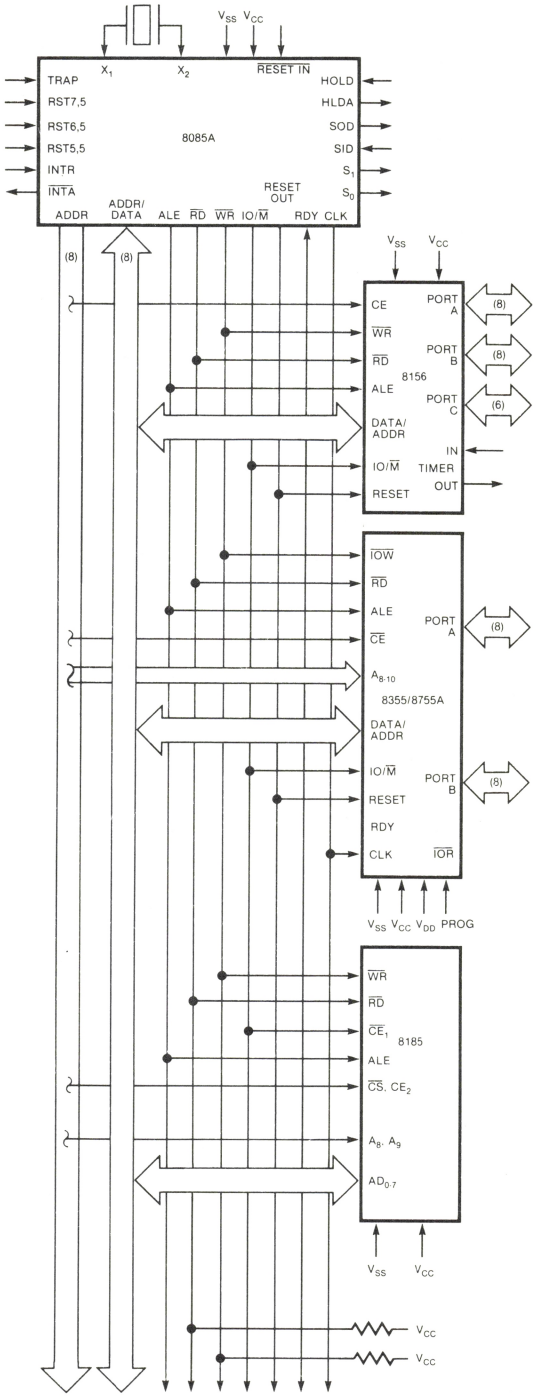
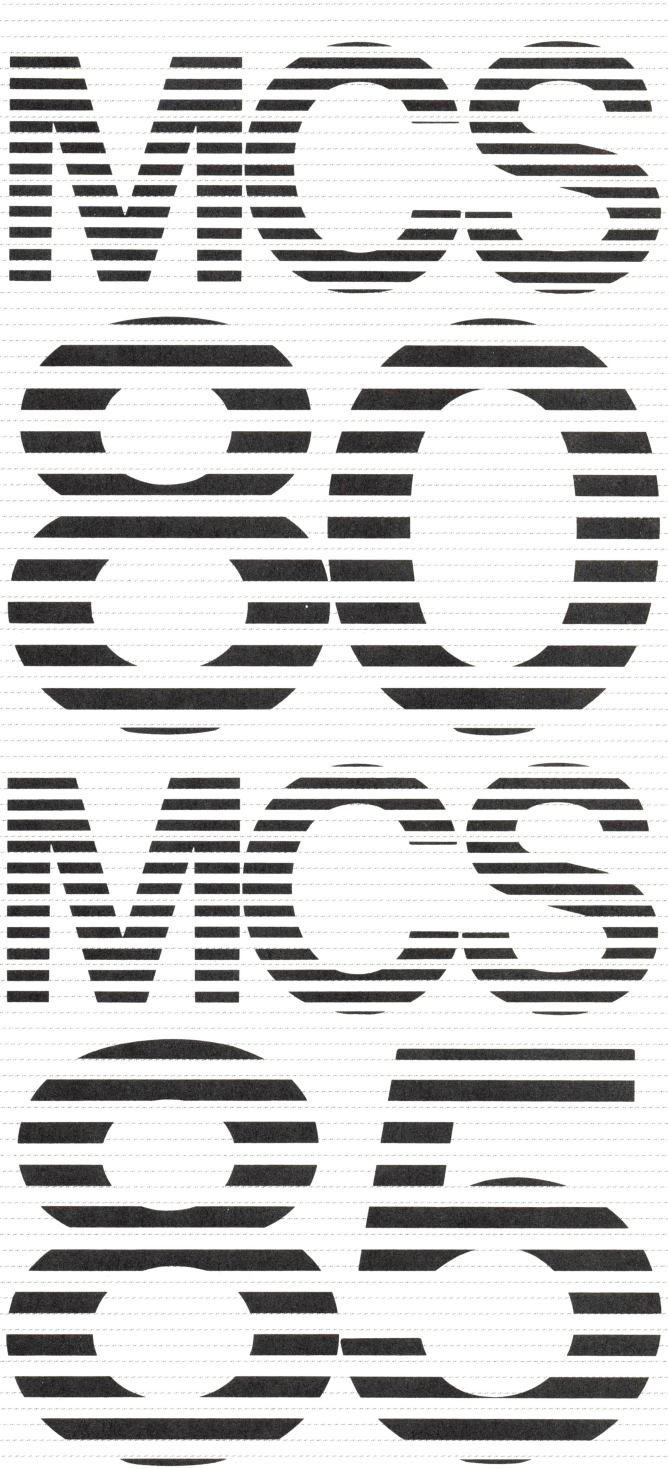


FIGURE 3-9 MCS-85 SYSTEM WITH 8185

Chapter 4
8080A Functional Description



CHAPTER 4
THE 8080 CENTRAL PROCESSOR UNIT

The 8080 is a complete 8-bit parallel, central processor unit (CPU) for use in general purpose digital computer systems. It is fabricated on a single LSI chip (see Figure 1-1). using Intel's n-channel silicon gate MOS process. The 8080 transfers data and internal state information via an 8-bit, bidirectional 3-state Data Bus (D_0-D_7). Memory and peripheral device addresses are transmitted over a separate 16-bit 3-state Address Bus (A_0-A_{15}). Six timing and control outputs (SYNC, DBIN, WAIT, $\overline{WR}$, HLDA and INTE) emanate from the 8080, while four control inputs (READY, HOLD, INT and RESET), four power inputs (+12v, +5v, -5v, and GND) and two clock inputs (ϕ_1 and ϕ_2) are accepted by the 8080.

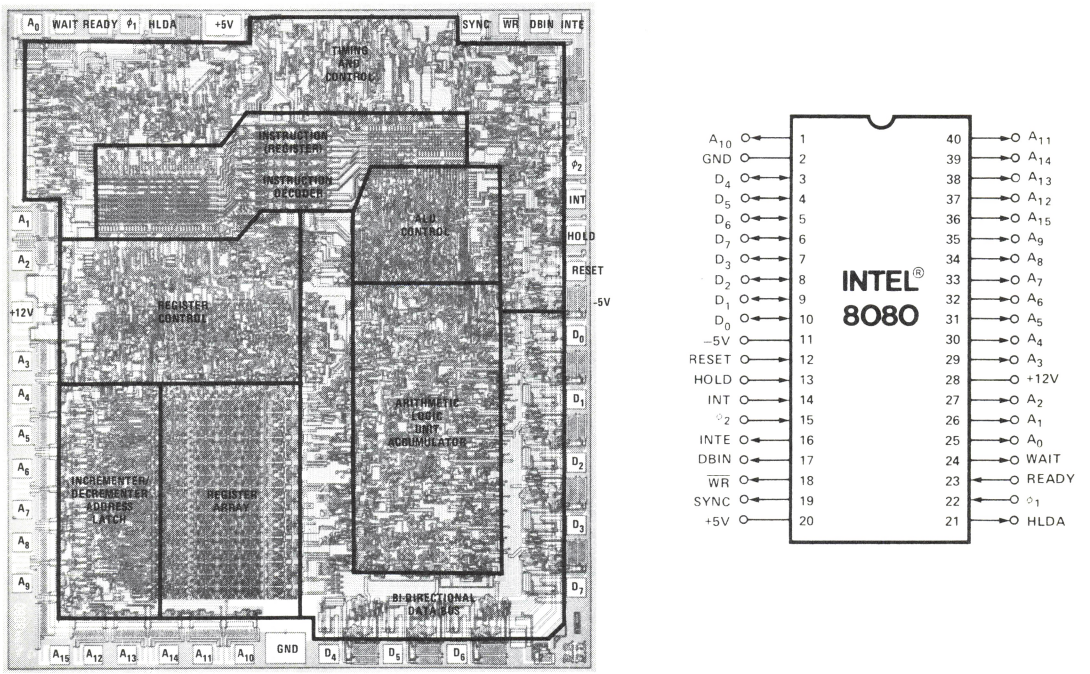


Figure 4-1. 8080 Photomicrograph With Pin Designations

ARCHITECTURE OF THE 8080 CPU

The 8080 CPU consists of the following functional units:

- Register array and address logic
- Arithmetic and logic unit (ALU)
- Instruction register and control section
- Bi-directional, 3-state data bus buffer

Figure 4-2 illustrates the functional blocks within the 8080 CPU.

Registers:

The register section consists of a static RAM array organized into six 16-bit registers:

- Program counter (PC)
- Stack pointer (SP)
- Six 8-bit general purpose registers arranged in pairs, referred to as B,C; D,E; and H,L
- A temporary register pair called W,Z

The program counter maintains the memory address of the next program instruction and is incremented automatically during every instruction fetch. The stack pointer maintains the address of the next available stack location in memory. The stack pointer can be initialized to use any portion of read-write memory as a stack. The stack pointer is decremented when data is "pushed" onto the stack and incremented when data is "popped" off the stack (i.e., the stack grows "downward").

The six general purpose registers can be used either as single registers (8-bit) or as register pairs (16-bit). The temporary register pair, W,Z, is not program addressable and is only used for the internal execution of instructions.

Eight-bit data bytes can be transferred between the internal bus and the register array via the register-select multiplexer. Sixteen-bit transfers can proceed between the register array and the address latch or the incrementer/decrementer circuit. The address latch receives data from any of the four register pairs and drives the 16 address output buffers (A_0-A_{15}), as well as the incrementer/decrementer circuit. The incrementer/decrementer circuit receives data from the address latch and sends it to the register array. The 16-bit data can be incremented or decremented or simply transferred between registers.

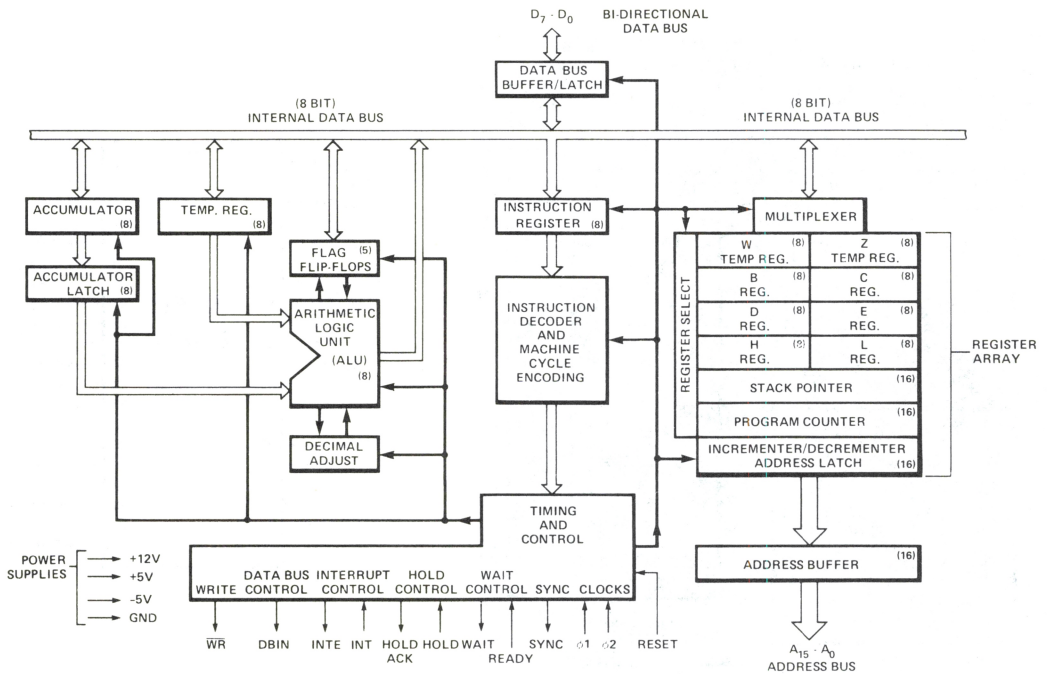


Figure 4-2. 8080 CPU Functional Block Diagram

Arithmetic and Logic Unit (ALU):

The ALU contains the following registers:

- An 8-bit accumulator
- An 8-bit temporary accumulator (ACT)
- A 5-bit flag register: zero, carry, sign, parity and auxiliary carry
- An 8-bit temporary register (TMP)

Arithmetic, logical and rotate operations are performed in the ALU. The ALU is fed by the temporary register (TMP) and the temporary accumulator (ACT) and carry flip-flop. The result of the operation can be transferred to the internal bus or to the accumulator; the ALU also feeds the flag register.

The temporary register (TMP) receives information from the internal bus and can send all or portions of it to the ALU, the flag register and the internal bus.

The accumulator (ACC) can be loaded from the ALU and the internal bus and can transfer data to the temporary accumulator (ACT) and the internal bus. The contents of the accumulator (ACC) and the auxiliary carry flip-flop can be tested for decimal correction during the execution of the DAA instruction (see Section 5).

Instruction Register and Control:

During an instruction fetch, the first byte of an instruction (containing the OP code) is transferred from the internal bus to the 8-bit instruction register.

The contents of the instruction register are, in turn, available to the instruction decoder. The output of the decoder, combined with various timing signals, provides the control signals for the register array, ALU and data buffer blocks. In addition, the outputs from the instruction decoder and external control signals feed the timing and state control section which generates the state and cycle timing signals.

Data Bus Buffer:

This 8-bit bidirectional 3-state buffer is used to isolate the CPU's internal bus from the external data bus (D_0 through D_7). In the output mode, the internal bus content is loaded into an 8-bit latch that, in turn, drives the data bus output buffers. The output buffers are switched off during input or non-transfer operations.

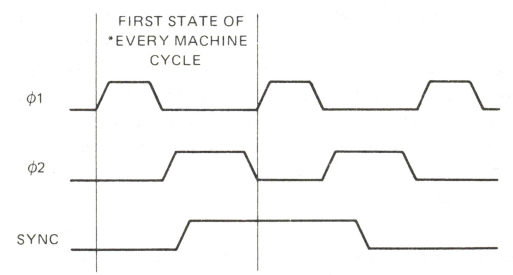
During the input mode, data from the external data bus is transferred to the internal bus. The internal bus is precharged at the beginning of each internal state, except for the transfer state (TW and T_3—described later in this chapter).

THE PROCESSOR CYCLE

An **instruction cycle** is defined as the time required to fetch and execute an instruction. During the fetch, a selected instruction (one, two or three bytes) is extracted from memory and deposited in the CPU's instruction register. During the execution phase, the instruction is decoded and translated into specific processing activities.

Every instruction cycle consists of one, two, three, four or five machine cycles. A **machine cycle** is required each time the CPU accesses memory or an I/O port. The fetch portion of an instruction cycle requires one machine cycle for each byte to be fetched. The duration of the execution portion of the instruction cycle depends on the kind of instruction that has been fetched. Some instructions do not require any machine cycles other than those necessary to fetch the instruction; other instructions, however, require additional machine cycles to write or read data to/from memory or I/O devices. The DAD instruction is an exception in that it requires two additional machine cycles to complete an internal register-pair add (see Section 5).

Each machine cycle consists of three, four or five states. A state is the smallest unit of processing activity and is defined as the interval between two successive positive-going transitions of the ϕ_1 driven clock pulse. The 8080 is driven by a two-phase clock oscillator. All processing activities are referred to the period of this clock. The two non-overlapping clock pulses, labeled ϕ_1 and ϕ_2, are furnished by external circuitry. It is the ϕ_1 clock pulse which divides each machine cycle into states. Timing logic within the 8080 uses the clock inputs to produce a SYNC pulse, which identifies the beginning of every machine cycle. The SYNC pulse is triggered by the low-to-high transition of ϕ_2, as shown in Figure 4-3.



*SYNC DOES NOT OCCUR IN THE SECOND AND THIRD MACHINE CYCLES OF A DAD INSTRUCTION SINCE THESE MACHINE CYCLES ARE USED FOR AN INTERNAL REGISTER-PAIR ADD.

Figure 4-3. ϕ_1, ϕ_2 and SYNC Timing

There are three exceptions to the defined duration of a state. They are the WAIT state, the hold (HLDA) state and the halt (HLTA) state, described later in this chapter. Because the WAIT, the HLDA, and the HLTA states depend upon external events, they are by their nature of indeterminate length. Even these exceptional states, however, must

be synchronized with the pulses of the driving clock. Thus, the duration of all states are integral multiples of the clock period.

To summarize then, each **clock period** marks a **state;** three to five states constitute a machine cycle; and one to five **machine cycles** comprise an **instruction cycle.** A full instruction cycle requires anywhere from four to eighteen states for its completion, depending on the kind of instruction involved.

Machine Cycle Identification:

With the exception of the DAD instruction, there is just one consideration that determines how many machine cycles are required in any given instruction cycle: the number of times that the processor must reference a memory address or an addressable peripheral device, in order to fetch and execute the instruction. Like many processors, the 8080 is so constructed that it can transmit only one address per machine cycle. Thus, if the fetch and execution of an instruction requires two memory references, then the instruction cycle associated with that instruction consists of two machine cycles. If five such references are called for, then the instruction cycle contains five machine cycles.

Every instruction cycle has at least one reference to memory, during which the instruction is fetched. An instruction cycle must always have a fetch, even if the execution of the instruction requires no further references to memory. The first machine cycle in every instruction cycle is therefore a FETCH. Beyond that, there are no fast rules. It depends on the kind of instruction that is fetched.

Consider some examples. The add-register (ADD r) instruction is an instruction that requires only a single machine cycle (FETCH) for its completion. In this one-byte instruction, the contents of one of the CPU's six general purpose registers is added to the existing contents of the accumulator. Since all the information necessary to execute the command is contained in the eight bits of the instruction code, only one memory reference is necessary. Three states are used to extract the instruction from memory, and one additional state is used to accomplish the desired addition. The entire instruction cycle thus requires only one machine cycle that consists of four states, or four periods of the external clock.

Suppose now, however, that we wish to add the contents of a specific memory location to the existing contents of the accumulator (ADD M). Although this is quite similar in principle to the example just cited, several additional steps will be used. An extra machine cycle will be used, in order to address the desired memory location.

The actual sequence is as follows. First the processor extracts from memory the one-byte instruction word addressed by its program counter. This takes three states. The eight-bit instruction word obtained during the FETCH machine cycle is deposited in the CPU's instruction register and used to direct activities during the remainder of the instruction cycle. Next, the processor sends out, as an address, the contents of its H and L registers. The eight-bit data word returned during this MEMORY READ machine cycle is placed in a temporary register inside the 8080 CPU. By now three more clock periods (states) have elapsed. In the seventh and final state, the contents of the temporary register are added to those of the accumulator. Two machine cycles, consisting of seven states in all, complete the "ADD M" instruction cycle.

At the opposite extreme is the save H and L registers (SHLD) instruction, which requires five machine cycles. During an "SHLD" instruction cycle, the contents of the processor's H and L registers are deposited in two sequentially adjacent memory locations; the destination is indicated by two address bytes which are stored in the two memory locations immediately following the operation code byte. The following sequence of events occurs:

(1) A FETCH machine cycle, consisting of four states. During the first three states of this machine cycle, the processor fetches the instruction indicated by its program counter. The program counter is then incremented. The fourth state is used for internal instruction decoding.

(2) A MEMORY READ machine cycle, consisting of three states. During this machine cycle, the byte indicated by the program counter is read from memory and placed in the processor's Z register. The program counter is incremented again.

(3) Another MEMORY READ machine cycle, consisting of three states, in which the byte indicated by the processor's program counter is read from memory and placed in the W register. The program counter is incremented, in anticipation of the next instruction fetch.

(4) A MEMORY WRITE machine cycle, of three states, in which the contents of the L register are transferred to the memory location pointed to by the present contents of the W and Z registers. The state following the transfer is used to increment the W,Z register pair so that it indicates the next memory location to receive data.

(5) A MEMORY WRITE machine cycle, of three states, in which the contents of the H register are transferred to the new memory location pointed to by the W,Z register pair.

In summary, the "SHLD" instruction cycle contains five machine cycles and takes 16 states to execute.

Most instructions fall somewhere between the extremes typified by the "ADD r" and the "SHLD" instructions. The input (IN) and the output (OUT) instructions, for example, require three machine cycles: a FETCH, to obtain the instruction; a MEMORY READ, to obtain the address of the object peripheral; and an INPUT or an OUTPUT machine cycle, to complete the transfer.

While no one instruction cycle will consist of more then five machine cycles, the following ten different types of machine cycles may occur within an instruction cycle:

(1) FETCH (M1)
(2) MEMORY READ
(3) MEMORY WRITE
(4) STACK READ
(5) STACK WRITE
(6) INPUT
(7) OUTPUT
(8) INTERRUPT
(9) HALT
(10) HALT • INTERRUPT

The machine cycles that actually do occur in a particular instruction cycle depend upon the kind of instruction, with the overriding stipulation that the first machine cycle in any instruction cycle is always a FETCH.

The processor identifies the machine cycle in progress by transmitting an eight-bit status word during the first state of every machine cycle. Updated status information is presented on the 8080's data lines (D_0-D_7), during the SYNC interval. This data should be saved in latches, and used to develop control signals for external circuitry. Table 4-1 shows how the positive-true status information is distributed on the processor's data bus.

Status signals are provided principally for the control of external circuitry. Simplicity of interface, rather than machine cycle identification, dictates the logical definition of individual status bits. You will therefore observe that certain processor machine cycles are uniquely identified by a single status bit, but that others are not. The M_1 status bit (D_5), for example, unambiguously identifies a FETCH machine cycle. A STACK READ, on the other hand, is indicated by the coincidence of STACK and MEMR signals. Machine cycle identification data is also valuable in the test and de-bugging phases of system development. Table 4-1 lists the status bit outputs for each type of machine cycle.

State Transition Sequence:

Every machine cycle within an instruction cycle consists of three to six active states (referred to as T_1, T_2, T_3, T_4, T_5 or T_W). The actual number of states depends upon the instruction being executed, and on the particular machine cycle within the greater instruction cycle. The state transition diagram in Figure 4-4 shows how the 8080 proceeds from state to state in the course of a machine cycle. The diagram also shows how the READY, HOLD, and INTERRUPT lines are sampled during the machine cycle, and how the conditions on these lines may modify the basic transition sequence. In the present discussion, we are concerned only with the basic sequence and with the READY function. The HOLD and INTERRUPT functions will be discussed later.

The 8080 CPU does not directly indicate its internal state by transmitting a "state control" output during each state; instead, the 8080 supplies direct control output (INTE, HLDA, DBIN, $\overline{WR}$ and WAIT) for use by external circuitry.

Recall that the 8080 passes through at least three states in every machine cycle, with each state defined by successive low-to-high transitions of the ϕ_1 clock. Figure 4-5 shows the timing relationships in a typical FETCH machine cycle. Events that occur in each state are referenced to transitions of the ϕ_1 and ϕ_2 clock pulses.

The SYNC signal identifies the first state (T_1) in every machine cycle. As shown in Figure 4-5, the SYNC signal is related to the leading edge of the ϕ_2 clock. There is a delay (t_{DC}) between the low-to-high transition of ϕ_2 and the positive-going edge of the SYNC pulse. There also is a corresponding delay (also t_{DC}) between the next ϕ_2 pulse and the falling edge of the SYNC signal. Status information is displayed on D_0-D_7 during the same ϕ_2 to ϕ_2 interval. Switching of the status signals is likewise controlled by ϕ_2.

The rising edge of ϕ_2 during T_1 also loads the processor's address lines (A_0-A15). These lines become stable within a brief delay (t_{DA}) of the ϕ_2 clocking pulse, and they remain stable until the first ϕ_2 pulse after state T_3. This gives the processor ample time to read the data returned from memory.

Once the processor has sent an address to memory, there is an opportunity for the memory to request a WAIT. This it does by pulling the processor's READY line low, prior to the "Ready set-up" interval (t_{RS}) which occurs during the ϕ_2 pulse within state T_2 or T_W. As long as the READY line remains low, the processor will idle, giving the memory time to respond to the addressed data request. Refer to Figure 4-5.

The processor responds to a wait request by entering an alternative state (T_W) at the end of T_2, rather than proceeding directly to the T_3 state. Entry into the T_W state is indicated by a WAIT signal from the processor, acknowledging the memory's request. A low-to-high transition on the WAIT line is triggered by the rising edge of the ϕ_1 clock and occurs within a brief delay (t_{DC}) of the actual entry into the T_W state.

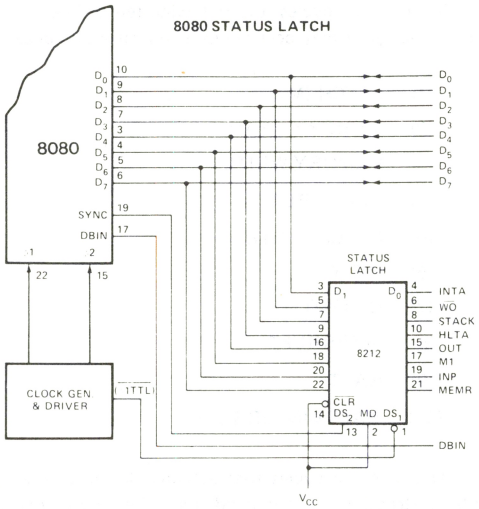
A wait period may be of indefinite duration. The processor remains in the waiting condition until its READY line again goes high. A READY indication **must** precede the falling edge of the ϕ_2 clock by a specified interval (t_{RS}), in order to guarantee an exit from the T_W state. The cycle may then proceed, beginning with the rising edge of the next ϕ_1 clock. A WAIT interval will therefore consist of an integral number of T_W states and will always be a multiple of the clock period.

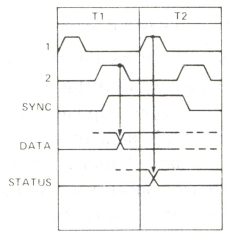
Instructions for the 8080 require from one to five machine cycles for complete execution. The 8080 sends out 8 bit of status information on the data bus at the beginning of each machine cycle (during SYNC time). The following table defines the status information.

STATUS INFORMATION DEFINITION

Symbols	Data Bus Bit	Definition
INTA*	D_0	Acknowledge signal for INTERRUPT request. Signal should be used to gate a restart instruction onto the data bus when DBIN is active.
$\overline{WO}$	D_1	Indicates that the operation in the current machine cycle will be a WRITE memory or OUTPUT function ($\overline{WO}$ = 0). Otherwise, a READ memory or INPUT operation will be executed.
STACK	D_2	Indicates that the address bus holds the pushdown stack address from the Stack Pointer.
HLTA	D_3	Acknowledge signal for HALT instruction.
OUT	D_4	Indicates that the address bus contains the address of an output device and the data bus will contain the output data when $\overline{WR}$ is active.
M_1	D_5	Provides a signal to indicate that the CPU is in the fetch cycle for the first byte of an instruction.
INP*	D_6	Indicates that the address bus contains the address of an input device and the input data should be placed on the data bus when DBIN is active.
MEMR*	D_7	Designates that the data bus will be used for memory read data.

*These three status bits can be used to control the flow of data onto the 8080 data bus.





STATUS WORD CHART

TYPE OF MACHINE CYCLE

	DATA BUS BIT	STATUS INFORMATION	(1) INSTRUCTION FETCH	(2) MEMORY READ	(3) MEMORY WRITE	(4) STACK READ	(5) STACK WRITE	(6) INPUT READ	(7) OUTPUT WRITE	(8) INTERRUPT ACKNOWLEDGE	(9) HALT ACKNOWLEDGE	(10) INTERRUPT ACKNOWLEDGE WHILE HALT
												(N) STATUS WORD
D_0	INTA		0	0	0	0	0	0	0	1	0	1
D_1	$\overline{WO}$		1	1	0	1	0	1	0	1	1	1
D_2	STACK		0	0	0	1	1	0	0	0	0	0
D_3	HLTA		0	0	0	0	0	0	0	0	1	1
D_4	OUT		0	0	0	0	0	0	1	0	0	0
D_5	M_1		1	0	0	0	0	0	0	1	0	1
D_6	INP		0	0	0	0	0	1	0	0	0	0
D_7	MEMR		1	1	0	1	0	0	0	0	1	0

Table 4-1. 8080 Status Bit Definitions

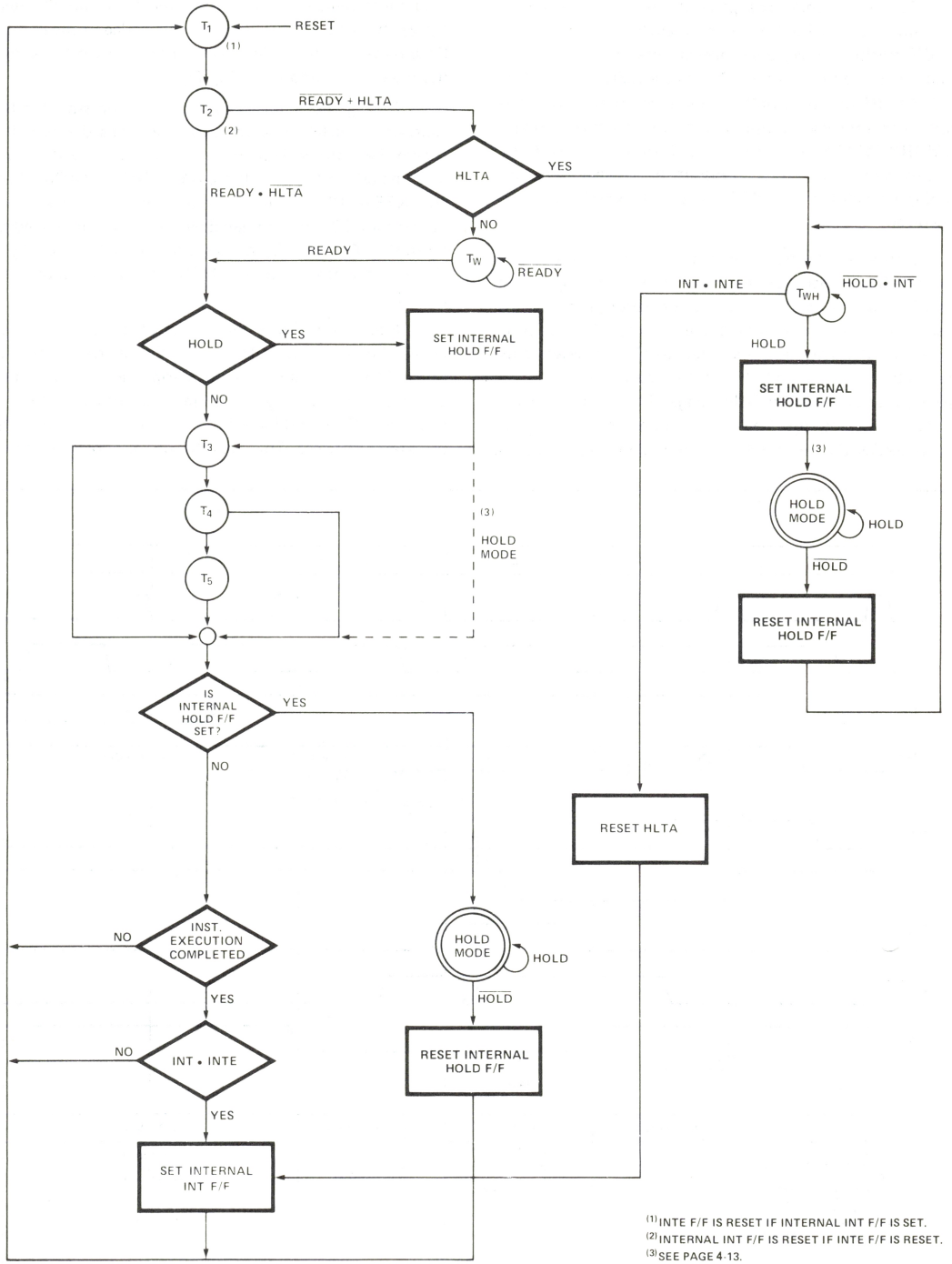


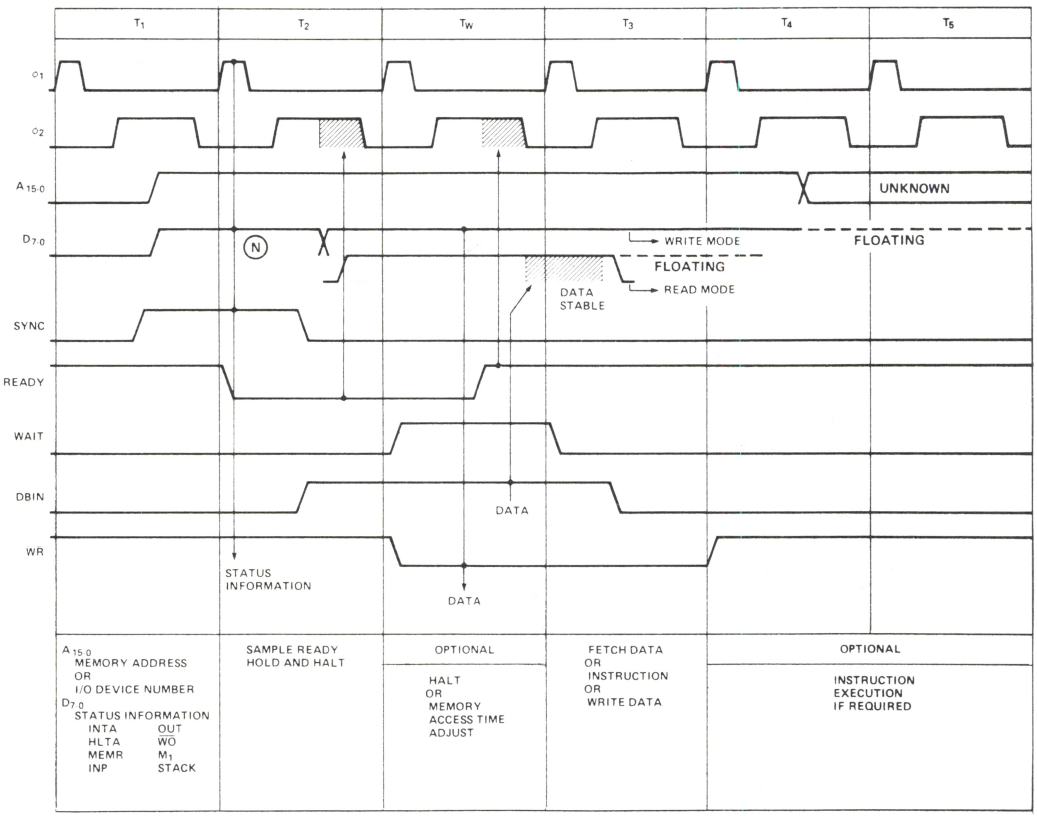
Figure 4-4. CPU State Transition Diagram

The events that take place during the T_3 state are determined by the kind of machine cycle in progress. In a FETCH machine cycle, the processor interprets the data on its data bus as an instruction. During a MEMORY READ or a STACK READ, data on this bus is interpreted as a data word. The processor outputs data on this bus during a MEMORY WRITE machine cycle. During I/O operations, the processor may either transmit or receive data, depending on whether an OUTPUT or an INPUT operation is involved.

Figure 4-7 illustrates the timing that is characteristic of a data input operation. As shown, the low-to-high transition of $\phi 2$ during T_2 clears status information from the processor's data lines, preparing these lines for the receipt of incoming data. The data presented to the processor must have stabilized prior to both the "$\phi 1$–data set-up" interval (t_{DS1}), that precedes the falling edge of the $\phi 1$ pulse defining state T_3, and the "$\phi 2$–data set-up" interval (t_{DS2}), that precedes the rising edge of $\phi 2$ in state T_3. This same data must remain stable during the "data hold" interval (t_{DH}) that occurs following the rising edge of the $\phi 2$ pulse. Data placed on these lines by memory or by other external devices will be sampled during T_3.

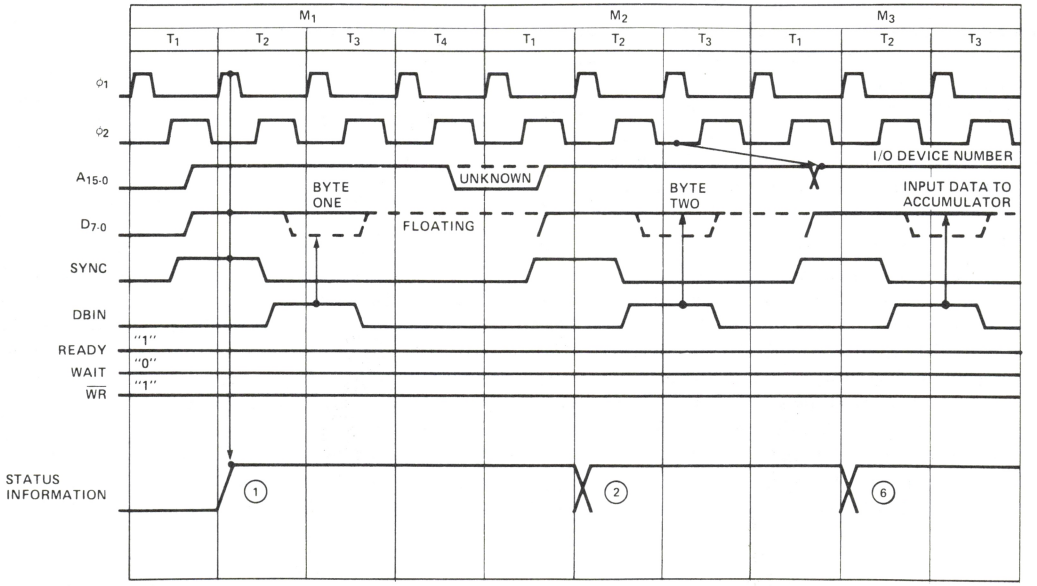
During the input of data to the processor, the 8080 generates a DBIN signal which should be used externally to enable the transfer. Machine cycles in which DBIN is available include: FETCH, MEMORY READ, STACK READ, and INTERRUPT. DBIN is initiated by the rising edge of $\phi 2$ during state T2 and terminated by the corresponding edge of $\phi 2$ during T_3. Any T_W phases intervening between T_2 and T_3 will therefore extend DBIN by one or more clock periods.

Figure 4-7 shows the timing of a machine cycle in which the processor outputs data. Output data may be destined either for memory or for peripherals. The rising edge of $\phi 2$ within state T_2 clears status information from the CPU's data lines, and loads in the data which is to be output to external devices. This substitution takes place within the



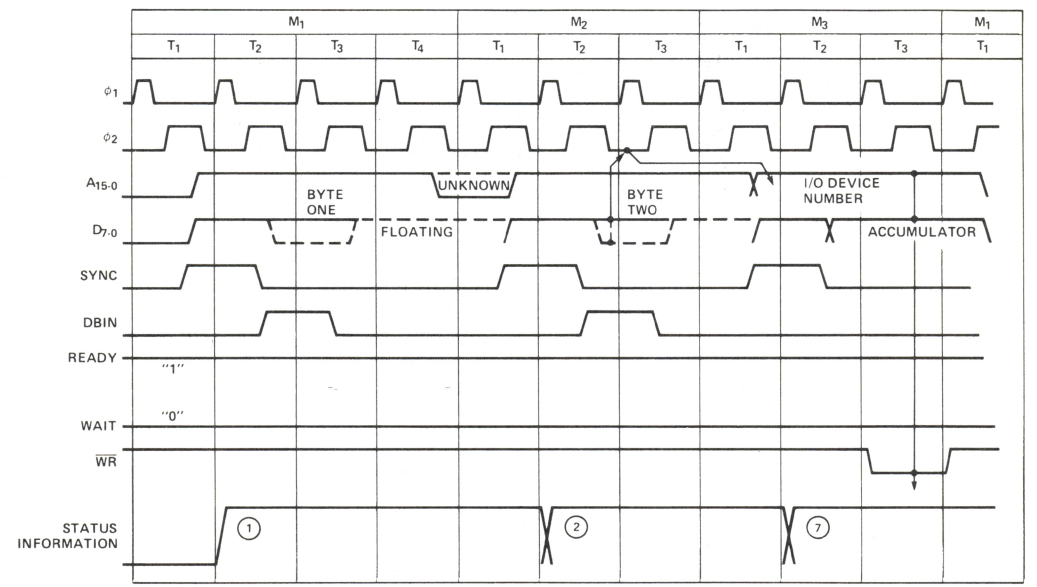
NOTE: (N) Refer to Status Word Chart on Page 4-6.

Figure 4-5. Basic 8080 Instruction Cycle



NOTE: (N) Refer to Status Word Chart on Page 4-6.

Figure 4-6. Input Instruction Cycle



NOTE: (N) Refer to Status Word Chart on Page 4-6.

Figure 4-7. Output Instruction Cycle

"data output delay" interval (t_{DD}) following the ϕ_2 clock's leading edge. Data on the bus remains stable throughout the remainder of the machine cycle, until replaced by updated status information in the subsequent T_1 state. Observe that a READY signal is necessary for completion of an OUTPUT machine cycle. Unless such an indication is present, the processor enters the T_W state, following the T_2 state. Data on the output lines remains stable in the interim, and the processing cycle will not proceed until the READY line again goes high.

The 8080 CPU generates a $\overline{WR}$ output for the synchronization of external transfers, during those machine cycles in which the processor outputs data. These include MEMORY WRITE, STACK WRITE, and OUTPUT. The negative-going leading edge of $\overline{WR}$ is referenced to the rising edge of the first ϕ_1 clock pulse following T_2, and occurs within a brief delay (t_{DC}) of that event. $\overline{WR}$ remains low until re-triggered by the leading edge of ϕ_1 during the state following T_3. Note that any T_W states intervening between T_2 and T_3 of the output machine cycle will necessarily extend $\overline{WR}$, in much the same way that DBIN is affected during data input operations.

All processor machine cycles consist of at least three states: T_1, T_2, and T_3 as just described. If the processor has to wait for a response from the peripheral or memory with which it is communicating, then the machine cycle may also contain one or more T_W states. During the three basic states, data is transferred to or from the processor.

After the T_3 state, however, it becomes difficult to generalize. T_4 and T_5 states are available, if the execution of a particular instruction requires them. But not all machine cycles make use of these states. It depends upon the kind of instruction being executed, and on the particular machine cycle within the instruction cycle. The processor will terminate any machine cycle as soon as its processing activities are completed, rather than proceeding through the T_4 and T_5 states every time. Thus the 8080 may exit a machine cycle following the T_3, the T_4, or the T_5 state and proceed directly to the T_1 state of the next machine cycle.

STATE	ASSOCIATED ACTIVITIES
T_1	A memory address or I/O device number is placed on the Address Bus (A_{15-0}); status information is placed on Data Bus (D_{7-0}).
T_2	The CPU samples the READY and HOLD inputs and checks for halt instruction.
TW (optional)	Processor enters wait state if READY is low or if HALT instruction has been executed.
T3	An instruction byte (FETCH machine cycle), data byte (MEMORY READ, STACK READ, INPUT) or interrupt instruction (INTERRUPT machine cycle) is input to the CPU from the Data Bus; or a data byte (MEMORY WRITE, STACK WRITE or OUTPUT machine cycle) is output onto the data bus.
T4 T5 (optional)	States T_4 and T_5 are available if the execution of a particular instruction requires them; if not, the CPU may skip one or both of them. T_4 and T_5 are only used for internal processor operations.

Table 4-2. State Definitions

INTERRUPT SEQUENCES

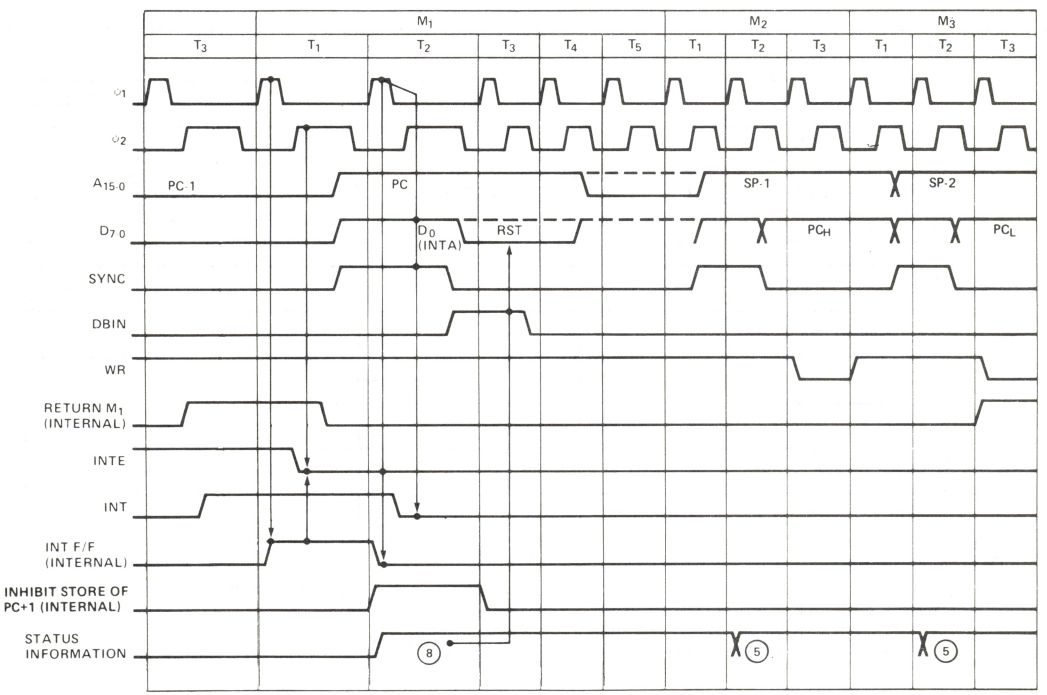
The 8080 has the built-in capacity to handle external interrupt requests. A peripheral device can initiate an interrupt simply by driving the processor's interrupt (INT) line high.

The interrupt (INT) input is asynchronous, and a request may therefore originate at any time during any instruction cycle. Internal logic re-clocks the external request, so that a proper correspondence with the driving clock is established. As Figure 4-8 shows, an interrupt request (INT) arriving during the time that the interrupt enable line (INTE) is high, acts in coincidence with the $\phi 2$ clock to set the internal interrupt latch. This event takes place during the last state of the instruction cycle in which the request occurs, thus ensuring that any instruction in progress is completed before the interrupt can be processed.

The INTERRUPT machine cycle which follows the arrival of an enabled interrupt request resembles an ordinary FETCH machine cycle in most respects. The M_1 status bit is transmitted as usual during the SYNC interval. It is accompanied, however, by an INTA status bit (D_0) which acknowledges the external request. The contents of the program counter are latched onto the CPU's address lines during T_1, but the counter itself is not incremented during the INTERRUPT machine cycle, as it otherwise would be. In this way, the pre-interrupt status of the program counter is preserved, so that data in the counter may be restored by the interrupted program after the interrupt request has been processed.

The interrupt cycle is otherwise indistinguishable from an ordinary FETCH machine cycle. The processor itself takes no further special action. It is the responsibility of the peripheral logic to see that an eight-bit interrupt instruction is "jammed" onto the processor's data bus during state T_3. In a typical system, this means that the data-in bus from memory must be temporarily disconnected from the processor's main data bus, so that the interrupting device can command the main bus without interference.

The 8080's instruction set provides a special one-byte call which facilitates the processing of interrupts (the ordinary program Call takes three bytes). This is the RESTART instruction (RST). A variable three-bit field embedded in the eight-bit field of the RST enables the interrupting device to direct a Call to one of eight fixed memory locations. The decimal addresses of these dedicated locations are: 0, 8, 16, 24, 32, 40, 48, and 56. Any of these addresses may be used to store the first instruction(s) of a routine designed to service the requirements of an interrupting device. Since the (RST) is a call, completion of the instruction also stores the old program counter contents on the STACK.



NOTE: (N) Refer to Status Word Chart on Page 4-6.

Figure 4-8. Interrupt Timing

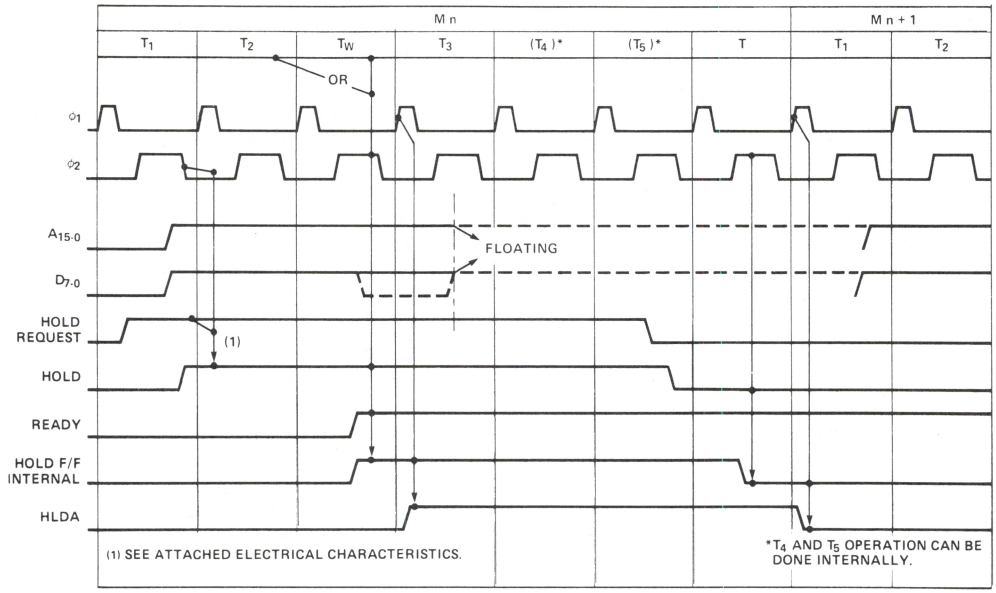


Figure 4-9. HOLD Operation (Read Mode)

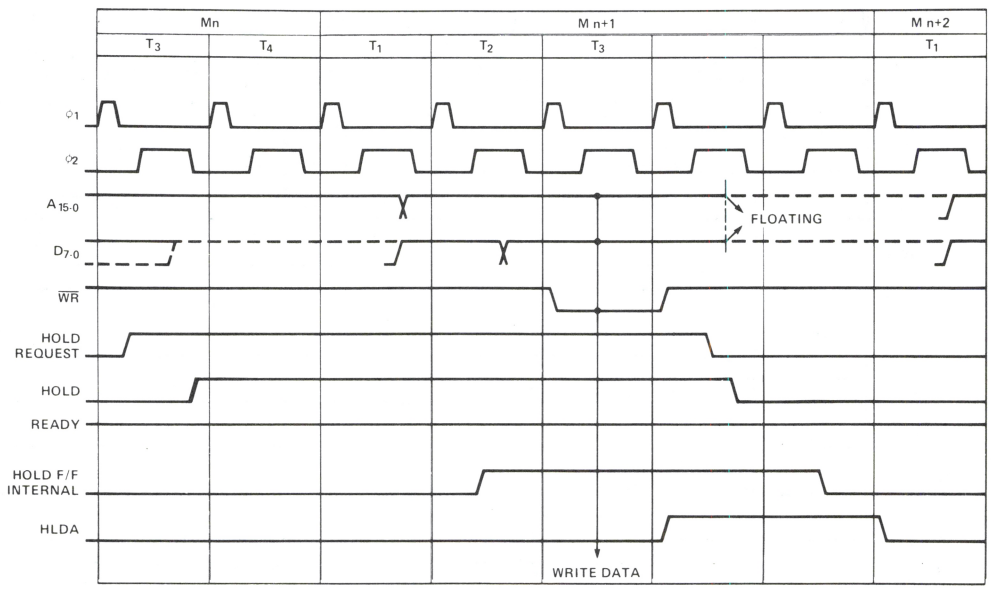


Figure 4-10. HOLD Operation (Write Mode)

HOLD SEQUENCES

The 8080A CPU contains provisions for Direct Memory Access (DMA) operations. By applying a HOLD to the appropriate control pin on the processor, an external device can cause the CPU to suspend its normal operations and relinquish control of the address and data busses. The processor responds to a request of this kind by floating its address to other devices sharing the busses. At the same time, the processor acknowledges the HOLD by placing a high on its HLDA outpin pin. During an acknowledged HOLD, the address and data busses are under control of the peripheral which originated the request, enabling it to conduct memory transfers without processor intervention.

Like the interrupt, the HOLD input is synchronized internally. A HOLD signal must be stable prior to the "Hold set-up" interval (t_{HS}), that precedes the rising edge of ϕ_2.

Figures 4-9 and 4-10 illustrate the timing involved in HOLD operations. Note the delay between the asynchronous HOLD REQUEST and the re-clocked HOLD. As shown in the diagram, a coincidence of the READY, the HOLD, and the ϕ_2 clocks sets the internal hold latch. Setting the latch enables the subsequent rising edge of the ϕ_1 clock pulse to trigger the HLDA output as described below.

Acknowledgement of the HOLD REQUEST precedes slightly the actual floating of the processor's address and data lines. The processor acknowledges a HOLD at the beginning of T_3, if a read or an input machine cycle is in progress (see Figure 4-9). Otherwise, acknowledgement is deferred until the beginning of the state following T_3 (see Figure 4-10). In both cases, however, the HLDA goes high within a specified delay (t_{DC}) of the rising edge of the selected ϕ_1 clock pulse. Address and data lines are floated within a brief delay after the rising edge of the next ϕ_2 clock pulse. This relationship is also shown in the diagrams.

To all outward appearances, the processor has suspended its operations once the address and data busses are floated. Internally, however, certain functions may continue. If a HOLD REQUEST is acknowledged at T_3, and if the processor is in the middle of a machine cycle which requires four or more states to complete, the CPU proceeds through T_4 and T_5 before coming to a rest. Not until the end of the machine cycle is reached will processing activities cease. Internal processing is thus permitted to overlap the external DMA transfer, improving both the efficiency and the speed of the entire system.

The processor exits the holding state through a sequence similar to that by which it entered. A HOLD REQUEST is terminated asynchronously when the external device has completed its data transfer. The HLDA output returns to a low level following the leading edge of the next $\phi 1$ clock pulse. Normal processing resumes with the machine cycle following the last cycle that was executed.

HALT SEQUENCES

When a halt instruction (HLT) is executed, the CPU enters the halt state (T_{WH}) after state T_2 of the next machine cycle, as shown in Figure 4-11. There are only three ways in which the 8080 can exit the halt state:

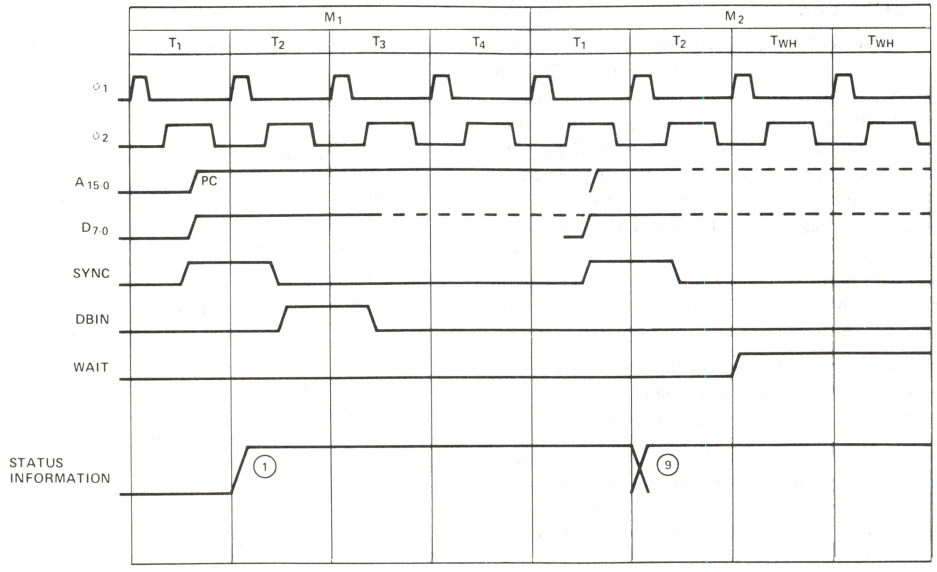
- A high on the RESET line will always reset the 8080 to state T_1; RESET also clears the program counter.
- A HOLD input will cause the 8080 to enter the hold state, as previously described. When the HOLD line goes low, the 8080 re-enters the halt state on the rising edge of the next ϕ_1 clock pulse.
- An interrupt (i.e., INT goes high while INTE is enabled) will cause the 8080 to exit the Halt state and enter state T_1 on the rising edge of the next ϕ_1 clock pulse. NOTE: The interrupt enable (INTE) flag **must** be set when the halt state is entered; otherwise, the 8080 will only be able to exit via a RESET signal.

Figure 4-12 illustrates halt sequencing in flow chart form.

START-UP OF THE 8080 CPU

When power is applied initially to the 8080, the processor begins operating immediately. The contents of its program counter, stack pointer, and the other working registers are naturally subject to random factors and cannot be specified. For this reason, it will be necessary to begin the power-up sequence with RESET.

An external RESET signal of three clock period duration (minimum) restores the processor's internal program counter to zero. Program execution thus begins with memory location zero, following a RESET. Systems which require the processor to wait for an explicit start-up signal will store a halt instruction (EI, HLT) in the first two locations. A manual or an automatic INTERRUPT will be used for starting. In other systems, the processor may begin executing its stored program immediately. Note, however, that the RESET has no effect on status flags, or on any of the processor's working registers (accumulator, registers, or stack pointer). The contents of these registers remain indeterminate, until initialized explicitly by the program.



NOTE: (N) Refer to Status Word Chart on Page 4-6

Figure 4-11. HALT Timing

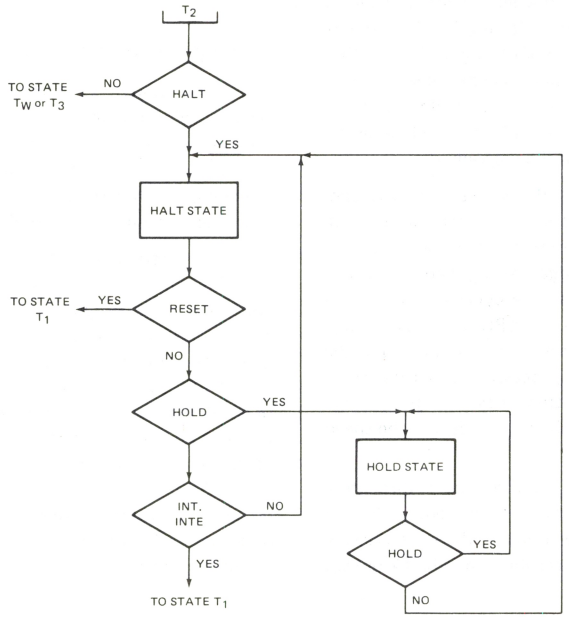
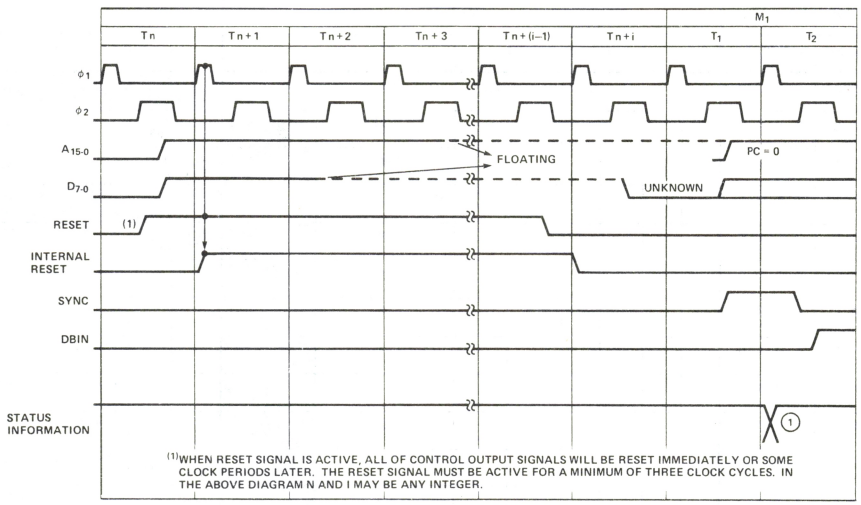
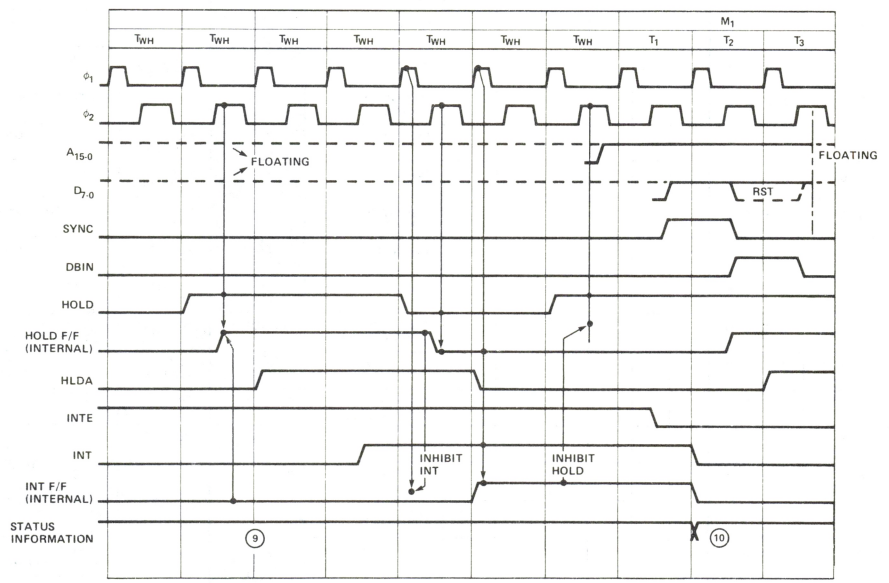


Figure 4-12. HALT Sequence Flow Chart



NOTE: (N) Refer to Status Word Chart on Page 4-6.

Figure 4-13. Reset



NOTE: (N) Refer to Status Word Chart on Page 4-6.

Figure 4-14. Relation between HOLD and INT in the HALT State

MNEMONIC	OP CODE		M1[1]					M2		
	$D_7 D_6 D_5 D_4$	$D_3 D_2 D_1 D_0$	T1	T2[2]	T3	T4	T5	T1	T2[2]	T3
MOV r1, r2	0 1 D D	D S S S	PC OUT STATUS	PC = PC +1	INST→TMP/IR	(SSS)→TMP	(TMP)→DDD			
MOV r, M	0 1 D D	D 1 1 0	↑	↑	↑	X[3]		HL OUT STATUS[6]	DATA →	DDD
MOV M, r	0 1 1 1	0 S S S	↑	↑	↑	(SSS)→TMP		HL OUT STATUS[7]	(TMP) →	DATA BUS
SPHL	1 1 1 1	1 0 0 1	↑	↑	↑	(HL) →	SP			
MVI r, data	0 0 D D	D 1 1 0	↑	↑	↑	X		PC OUT STATUS[6]	PC = PC + 1 B2 →	DDD
MVI M, data	0 0 1 1	0 1 1 0	↑	↑	↑	X		↑	PC = PC + 1 B2 →	TMP
LXI rp, data	0 0 R P	0 0 0 1	↑	↑	↑	X		↑	PC = PC + 1 B2 →	rl
LDA addr	0 0 1 1	1 0 1 0	↑	↑	↑	X		↑	PC = PC + 1 B2 →	Z
STA addr	0 0 1 1	0 0 1 0	↑	↑	↑	X		↑	PC = PC + 1 B2 →	Z
LHLD addr	0 0 1 0	1 0 1 0	↑	↑	↑	X		↑	PC = PC + 1 B2 →	Z
SHLD addr	0 0 1 0	0 0 1 0	↑	↑	↑	X		PC OUT STATUS[6]	PC = PC + 1 B2 →	Z
LDAX rp[4]	0 0 R P	1 0 1 0	↑	↑	↑	X		rp OUT STATUS[6]	DATA →	A
STAX rp[4]	0 0 R P	0 0 1 0	↑	↑	↑	X		rp OUT STATUS[7]	(A) →	DATA BUS
XCHG	1 1 1 0	1 0 1 1	↑	↑	↑	X		[11]	(HL) ↔ (DE)	
ADD r	1 0 0 0	0 S S S	↑	↑	↑	(SSS)→TMP (A)→ACT		[9]	(ACT)+(TMP)→A	
ADD M	1 0 0 0	0 1 1 0	↑	↑	↑	(A)→ACT		HL OUT STATUS[6]	DATA →	TMP
ADI data	1 1 0 0	0 1 1 0	↑	↑	↑	(A)→ACT		PC OUT STATUS[6]	PC = PC + 1 B2 →	TMP
ADC r	1 0 0 0	1 S S S	↑	↑	↑	(SSS)→TMP (A)→ACT		[9]	(ACT)+(TMP)+CY→A	
ADC M	1 0 0 0	1 1 1 0	↑	↑	↑	(A)→ACT		HL OUT STATUS[6]	DATA →	TMP
ACI data	1 1 0 0	1 1 1 0	↑	↑	↑	(A)→ACT		PC OUT STATUS[6]	PC = PC + 1 B2 →	TMP
SUB r	1 0 0 1	0 S S S	↑	↑	↑	(SSS)→TMP (A)→ACT		[9]	(ACT)-(TMP)→A	
SUB M	1 0 0 1	0 1 1 0	↑	↑	↑	(A)→ACT		HL OUT STATUS[6]	DATA →	TMP
SUI data	1 1 0 1	0 1 1 0	↑	↑	↑	(A)→ACT		PC OUT STATUS[6]	PC = PC + 1 B2 →	TMP
SBB r	1 0 0 1	1 S S S	↑	↑	↑	(SSS)→TMP (A)→ACT		[9]	(ACT)-(TMP)-CY→A	
SBB M	1 0 0 1	1 1 1 0	↑	↑	↑	(A)→ACT		HL OUT STATUS[6]	DATA →	TMP
SBI data	1 1 0 1	1 1 1 0	↑	↑	↑	(A)→ACT		PC OUT STATUS[6]	PC = PC + 1 B2 →	TMP
INR r	0 0 D D	D 1 0 0	↑	↑	↑	(DDD)→TMP (TMP) + 1→ALU	ALU→DDD			
INR M	0 0 1 1	0 1 0 0	↑	↑	↑	X		HL OUT STATUS[6]	DATA → (TMP)+1 →	TMP ALU
DCR r	0 0 D D	D 1 0 1	↑	↑	↑	(DDD)→TMP (TMP)-1→ALU	ALU→DDD			
DCR M	0 0 1 1	0 1 0 1	↑	↑	↑	X		HL OUT STATUS[6]	DATA → (TMP)-1 →	TMP ALU
INX rp	0 0 R P	0 0 1 1	↑	↑	↑	(RP) + 1 →	RP			
DCX rp	0 0 R P	1 0 1 1	↑	↑	↑	(RP) - 1 →	RP			
DAD rp[8]	0 0 R P	1 0 0 1	↑	↑	↑	X		(rl) →ACT	(L)→TMP, (ACT)+(TMP)→ALU	ALU→L, CY
DAA	0 0 1 0	0 1 1 1	↑	↑	↑	66→ACT [10] (A)→TMP		[9]	DAA →A FLAGS [10]	
ANA r	1 0 1 0	0 S S S	↑	↑	↑	(SSS)→TMP (A)→ACT		[9]	(ACT)+(TMP)→A	
ANA M	1 0 1 0	0 1 1 0	PC OUT STATUS	PC = PC + 1	INST→TMP/IR	(A)→ACT		HL OUT STATUS[6]	DATA →	TMP

M3			M4			M5				
T1	T2[2]	T3	T1	T2[2]	T3	T1	T2[2]	T3	T4	T5
HL OUT STATUS[7]	(TMP) → DATA BUS									
PC OUT STATUS[6]	PC = PC + 1 B3 → rh									
	PC = PC + 1 B3 → W		WZ OUT STATUS[6]	DATA → A						
	PC = PC + 1 B3 → W		WZ OUT STATUS[7]	(A) → DATA BUS						
	PC = PC + 1 B3 → W		WZ OUT STATUS[6]	DATA → L WZ = WZ + 1		WZ OUT STATUS[6]	DATA → H			
PC OUT STATUS[6]	PC = PC + 1 B3 → W		WZ OUT STATUS[7]	(L) → DATA BUS WZ = WZ + 1		WZ OUT STATUS[7]	(H) → DATA BUS			
[9]	(ACT)+(TMP)→A									
[9]	(ACT)+(TMP)→A									
[9]	(ACT)+(TMP)+CY→A									
[9]	(ACT)+(TMP)+CY→A									
[9]	(ACT)-(TMP)→A									
[9]	(ACT)-(TMP)→A									
[9]	(ACT)-(TMP)-CY→A									
[9]	(ACT)-(TMP)-CY→A									
HL OUT STATUS[7]	ALU → DATA BUS									
HL OUT STATUS[7]	ALU → DATA BUS									
(rh)→ACT	(H)→TMP (ACT)+(TMP)+CY→ALU	ALU→H, CY								
[9]	(ACT)+(TMP)→A									

MNEMONIC	OP CODE		M1[1]					M2		
	$D_7 D_6 D_5 D_4$	$D_3 D_2 D_1 D_0$	T1	T2[2]	T3	T4	T5	T1	T2[2]	T3
ANI data	1 1 1 0	0 1 1 0	PC OUT STATUS	PC = PC + 1	INST→TMP/IR	(A)→ACT		PC OUT STATUS[6]	PC = PC + 1 B2	→TMP
XRA r	1 0 1 0	1 S S S				(A)→ACT (SSS)→TMP		[9]	(ACT)+(TPM)→A	
XRA M	1 0 1 0	1 1 1 0				(A)→ACT		HL OUT STATUS[6]	DATA	→TMP
XRI data	1 1 1 0	1 1 1 0				(A)→ACT		PC OUT STATUS[6]	PC = PC + 1 B2	→TMP
ORA r	1 0 1 1	0 S S S				(A)→ACT (SSS)→TMP		[9]	(ACT)+(TMP)→A	
ORA M	1 0 1 1	0 1 1 0				(A)→ACT		HL OUT STATUS[6]	DATA	→TMP
ORI data	1 1 1 1	0 1 1 0				(A)→ACT		PC OUT STATUS[6]	PC = PC + 1 B2	→TMP
CMP r	1 0 1 1	1 S S S				(A)→ACT (SSS)→TMP		[9]	(ACT)-(TMP), FLAGS	
CMP M	1 0 1 1	1 1 1 0				(A)→ACT		HL OUT STATUS[6]	DATA	→TMP
CPI data	1 1 1 1	1 1 1 0				(A)→ACT		PC OUT STATUS[6]	PC = PC + 1 B2	→TMP
RLC	0 0 0 0	0 1 1 1				(A)→ALU ROTATE		[9]	ALU→A, CY	
RRC	0 0 0 0	1 1 1 1				(A)→ALU ROTATE		[9]	ALU→A, CY	
RAL	0 0 0 1	0 1 1 1				(A), CY→ALU ROTATE		[9]	ALU→A, CY	
RAR	0 0 0 1	1 1 1 1				(A), CY→ALU ROTATE		[9]	ALU→A, CY	
CMA	0 0 1 0	1 1 1 1				A→ALU COMPLEMENT		[9]	ALU→A	
CMC	0 0 1 1	1 1 1 1				CY→ALU COMPLEMENT		[9]	ALU→CY	
STC	0 0 1 1	0 1 1 1				1→ALU		[9]	ALU→CY	
JMP addr	1 1 0 0	0 0 1 1				X		PC OUT STATUS[6]	PC = PC + 1 B2	→Z
J cond addr[17]	1 1 C C	C 0 1 0				JUDGE CONDITION		PC OUT STATUS[6]	PC = PC + 1 B2	→Z
CALL addr	1 1 0 0	1 1 0 1				SP = SP - 1		PC OUT STATUS[6]	PC = PC + 1 B2	→Z
C cond addr[17]	1 1 C C	C 1 0 0				JUDGE CONDITION IF TRUE, SP = SP - 1		PC OUT STATUS[6]	PC = PC + 1 B2	→Z
RET	1 1 0 0	1 0 0 1				X		SP OUT STATUS[15]	SP = SP + 1 DATA	→PCL
R cond addr[17]	1 1 C C	C 0 0 0			INST→TMP/IR	JUDGE CONDITION[14]		SP OUT STATUS[15]	SP = SP + 1 DATA	→PCL
RST n	1 1 N N	N 1 1 1			Φ→W INST→TMP/IR	SP = SP - 1		SP OUT STATUS[16]	SP = SP - 1 (PCH)	→DATA BUS
PCHL	1 1 1 0	1 0 0 1			INST→TMP/IR	(HL) → PC				
PUSH rp	1 1 R P	0 1 0 1				SP = SP - 1		SP OUT STATUS[16]	SP = SP - 1 (rh)	→DATA BUS
PUSH PSW	1 1 1 1	0 1 0 1				SP = SP - 1		SP OUT STATUS[16]	SP = SP - 1 (A)	→DATA BUS
POP rp	1 1 R P	0 0 0 1				X		SP OUT STATUS[15]	SP = SP + 1 DATA	→rl
POP PSW	1 1 1 1	0 0 0 1				X		SP OUT STATUS[15]	SP = SP + 1 DATA	→FLAGS
XTHL	1 1 1 0	0 0 1 1				X		SP OUT STATUS[15]	SP = SP + 1 DATA	→Z
IN port	1 1 0 1	1 0 1 1				X		PC OUT STATUS[6]	PC = PC + 1 B2	→Z, W
OUT port	1 1 0 1	0 0 1 1				X		PC OUT STATUS[6]	PC = PC + 1 B2	→Z, W
EI	1 1 1 1	1 0 1 1				X		SET INTE F/F [11]		
DI	1 1 1 1	0 0 1 1				X		RESET INTE F/F [11]		
HLT	0 1 1 1	0 1 1 0				X		PC OUT STATUS	HALT MODE[20]	
NOP	0 0 0 0	0 0 0 0	PC OUT STATUS	PC = PC + 1	INST→TMP/IR	X				

M3			M4			M5						
T1	T2[2]	T3	T1	T2[2]	T3	T1	T2[2]	T3	T4	T5		
[9]	(ACT)+(TMP)→A											
[9]	(ACT)+(TMP)→A											
[9]	(ACT)+(TMP)→A											
[9]	(ACT)+(TMP)→A											
[9]	(ACT)+(TMP)→A											
[9]	(ACT)-(TMP); FLAGS											
[9]	(ACT)-(TMP); FLAGS											
PC OUT STATUS[6]	PC = PC + 1 B3 → W										WZ OUT STATUS[11]	(WZ) + 1 → PC
PC OUT STATUS[6]	PC = PC + 1 B3 → W										WZ OUT STATUS[11,12]	(WZ) + 1 → PC
PC OUT STATUS[6]	PC = PC + 1 B3 → W		SP OUT STATUS[16]	(PCH) → DATA BUS SP = SP - 1		SP OUT STATUS[16]	(PCL) → DATA BUS				WZ OUT STATUS[11]	(WZ) + 1 → PC
PC OUT STATUS[6]	PC = PC + 1 B3 → W[13]		SP OUT STATUS[16]	(PCH) → DATA BUS SP = SP - 1		SP OUT STATUS[16]	(PCL) → DATA BUS				WZ OUT STATUS[11,12]	(WZ) + 1 → PC
SP OUT STATUS[15]	SP = SP + 1 DATA → PCH											
SP OUT STATUS[15]	SP = SP + 1 DATA → PCH											
SP OUT STATUS[16]	(TMP = 00NNN000) → Z (PCL) → DATA BUS										WZ OUT STATUS[11]	(WZ) + 1 → PC
SP OUT STATUS[16]	(rl) → DATA BUS											
SP OUT STATUS[16]	FLAGS → DATA BUS											
SP OUT STATUS[15]	SP = SP + 1 DATA → rh											
SP OUT STATUS[15]	SP = SP + 1 DATA → A											
SP OUT STATUS[15]	DATA → W		SP OUT STATUS[16]	(H) → DATA BUS SP = SP - 1		SP OUT STATUS[16]	(L) → DATA BUS		(WZ) → HL			
WZ OUT STATUS[18]	DATA → A											
WZ OUT STATUS[18]	(A) → DATA BUS											

NOTES:

1. The first memory cycle (M1) is always an instruction fetch; the first (or only) byte, containing the op code, is fetched during this cycle.

2. If the READY input from memory is not high during T2 of each memory cycle, the processor will enter a wait state (TW) until READY is sampled as high.

3. States T4 and T5 are present, as required, for operations which are completely internal to the CPU. The contents of the internal bus during T4 and T5 are available at the data bus; this is designed for testing purposes only. An "X" denotes that the state is present, but is only used for such internal operations as instruction decoding.

4. Only register pairs rp = B (registers B and C) or rp = D (registers D and E) may be specified.

5. These states are skipped.

6. Memory read sub-cycles; an instruction or data word will be read.

7. Memory write sub-cycle.

8. The READY signal is not required during the second and third sub-cycles (M2 and M3). The HOLD signal is accepted during M2 and M3. The SYNC signal is not generated during M2 and M3. During the execution of DAD, M2 and M3 are required for an internal register-pair add; memory is not referenced.

9. The results of these arithmetic, logical or rotate instructions are not moved into the accumulator (A) until state T2 of the next instruction cycle. That is, A is loaded while the next instruction is being fetched; this overlapping of operations allows for faster processing.

10. If the value of the least significant 4-bits of the accumulator is greater than 9 or if the auxiliary carry bit is set, 6 is added to the accumulator. If the value of the most significant 4-bits of the accumulator is now greater than 9, or if the carry bit is set, 6 is added to the most significant 4-bits of the accumulator.

11. This represents the first sub-cycle (the instruction fetch) of the next instruction cycle.

12. If the condition was met, the contents of the register pair WZ are output on the address lines ($A_{0\text{-}15}$) instead of the contents of the program counter (PC).

13. If the condition was not met, sub-cycles M4 and M5 are skipped; the processor instead proceeds immediately to the instruction fetch (M1) of the next instruction cycle.

14. If the condition was not met, sub-cycles M2 and M3 are skipped; the processor instead proceeds immediately to the instruction fetch (M1) of the next instruction cycle.

15. Stack read sub-cycle.

16. Stack write sub-cycle.

17.

CONDITION	CCC
NZ – not zero (Z = 0)	000
Z – zero (Z = 1)	001
NC – no carry (CY = 0)	010
C – carry (CY = 1)	011
PO – parity odd (P = 0)	100
PE – parity even (P = 1)	101
P – plus (S = 0)	110
M – minus (S = 1)	111

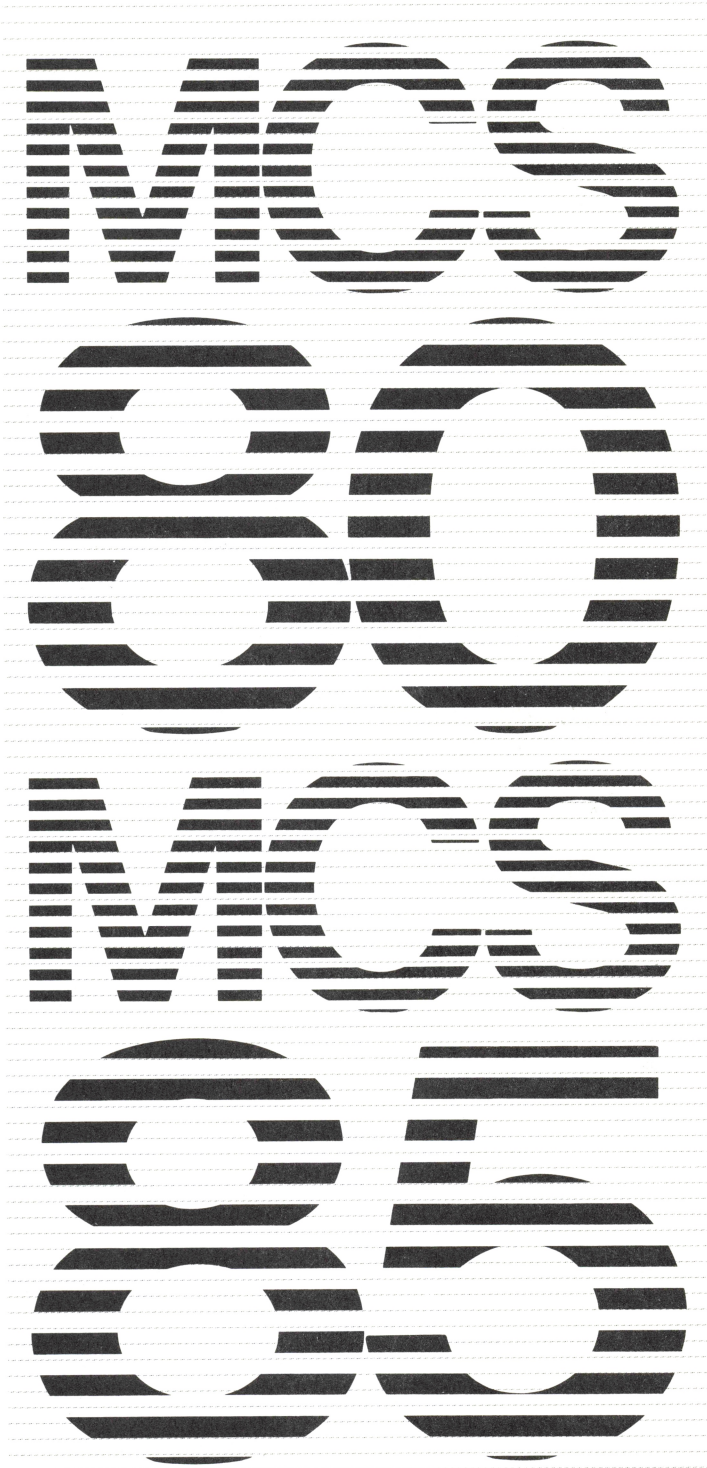
18. I/O sub-cycle: the I/O port's 8-bit select code is duplicated on address lines 0-7 ($A_{0\text{-}7}$) and 8-15 ($A_{8\text{-}15}$).

19. Output sub-cycle.

20. The processor will remain idle in the halt state until an interrupt, a reset or a hold is accepted. When a hold request is accepted, the CPU enters the hold mode; after the hold mode is terminated, the processor returns to the halt state. After a reset is accepted, the processor begins execution at memory location zero. After an interrupt is accepted, the processor executes the instruction forced onto the data bus (usually a restart instruction).

SSS or DDD	Value	rp	Value
A	111	B	00
B	000	D	01
C	001	H	10
D	010	SP	11
E	011		
H	100		
L	101		

Chapter 5
8080A/8085A
Instruction Set



CHAPTER 5
THE INSTRUCTION SET

5.1 WHAT THE INSTRUCTION SET IS

A computer, no matter how sophisticated, can do only what it is instructed to do. A program is a sequence of instructions, each of which is recognized by the computer and causes it to perform an operation. Once a program is placed in memory space that is accessible to your CPU, you may run that same sequence of instructions as often as you wish to solve the same problem or to do the same function. The set of instructions to which the 8085A CPU will respond is permanently fixed in the design of the chip.

Each computer instruction allows you to initiate the performance of a specific operation. The 8085A implements a group of instructions that move data between registers, between a register and memory, and between a register and an I/O port. It also has arithmetic and logic instructions, conditional and unconditional branch instructions, and machine control instructions. The CPU recognizes these instructions only when they are coded in binary form.

5.2 SYMBOLS AND ABBREVIATIONS:

The following symbols and abbreviations are used in the subsequent description of the 8085A instructions:

SYMBOLS	MEANING
accumulator	Register A
addr	16-bit address quantity
data	8-bit quantity
data 16	16-bit data quantity
byte 2	The second byte of the instruction
byte 3	The third byte of the instruction
port	8-bit address of an I/O device
r,r1,r2	One of the registers A,B,C, D,E,H,L
DDD,SSS	The bit pattern designating one of the registers A,B,C,D, E,H,L (DDD = destination, SSS = source):

DDD or SSS	REGISTER NAME
111	A
000	B
001	C
010	D
011	E
100	H
101	L

rp	One of the register pairs: B represents the B,C pair with B as the high-order register and C as the low-order register; D represents the D,E pair with D as the high-order register and E as the low-order register; H represents the H,L pair with H as the high-order register and L as the low-order register; SP represents the 16-bit stack pointer register.
RP	The bit pattern designating one of the register pairs B,D,H,SP:

RP	REGISTER PAIR
00	B-C
01	D-E
10	H-L
11	SP

rh	The first (high-order) register of a designated register pair.
rl	The second (low-order) register of a designated register pair.

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PC	16-bit program counter register (PCH and PCL are used to refer to the high-order and low-order 8 bits respectively).
SP	16-bit stack pointer register (SPH and SPL are used to refer to the high-order and low-order 8 bits respectively).
r_m	Bit m of the register r (bits are number 7 through 0 from left to right).
LABEL	16-bit address of subroutine.
	The condition flags:
Z	Zero
S	Sign
P	Parity
CY	Carry
AC	Auxiliary Carry
( )	The contents of the memory location or registers enclosed in the parentheses.
←	"Is transferred to"
∧	Logical AND
⊻	Exclusive OR
∨	Inclusive OR
+	Addition
–	Two's complement subtraction
*	Multiplication
↔	"Is exchanged with"
——	The one's complement (e.g., $\overline{(A)}$)
n	The restart number 0 through 7
NNN	The binary representation 000 through 111 for restart number 0 through 7 respectively.

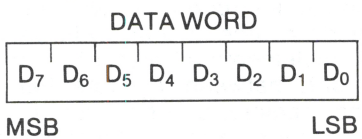
The instruction set encyclopedia is a detailed description of the 8085A instruction set. Each instruction is described in the following manner:

1. The MCS-85 macro assembler format, consisting of the instruction mnemonic and operand fields, is printed in **BOLDFACE** on the first line.
2. The name of the instruction is enclosed in parentheses following the mnemonic.
3. The next lines contain a symbolic description of what the instruction does.
4. This is followed by a narrative description of the operation of the instruction.
5. The boxes describe the binary codes that comprise the machine instruction.
6. The last four lines contain information about the execution of the instruction. The number of machine cycles and states required to execute the instruction are listed first. If the instruction has two possible execution times, as in a conditional jump, both times are listed, separated by a slash. Next, data addressing modes are listed if applicable. The last line lists any of the five flags that are affected by the execution of the instruction.

5.3 INSTRUCTION AND DATA FORMATS

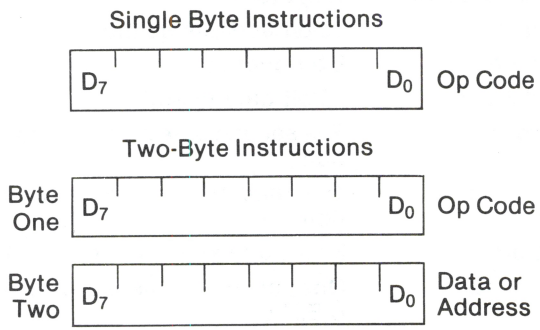
Memory used in the MCS-85 system is organized in 8-bit bytes. Each byte has a unique location in physical memory. That location is described by one of a sequence of 16-bit binary addresses. The 8085A can address up to 64K (K = 1024, or 2^{10}; hence, 64K represents the decimal number 65,536) bytes of memory, which may consist of both random-access, read-write memory (RAM) and read-only memory (ROM), which is also random-access.

Data in the 8085A is stored in the form of 8-bit binary integers:

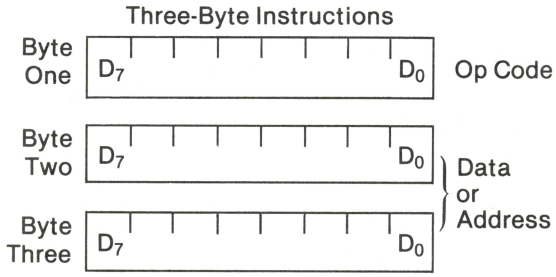


When a register or data word contains a binary number, it is necessary to establish the order in which the bits of the number are written. In the Intel 8085A, BIT 0 is referred to as the **Least Significant Bit (LSB),** and BIT 7 (of an 8-bit number) is referred to as the **Most Significant Bit (MSB).**

An 8085A program instruction may be one, two or three bytes in length. Multiple-byte instructions must be stored in successive memory locations; the address of the first byte is always used as the address of the instruction. The exact instruction format will depend on the particular operation to be executed.



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5.4 ADDRESSING MODES:

Often the data that is to be operated on is stored in memory. When multi-byte numeric data is used, the data, like instructions, is stored in successive memory locations, with the least significant byte first, followed by increasingly significant bytes. The 8085A has four different modes for addressing data stored in memory or in registers:

- Direct — Bytes 2 and 3 of the instruction contain the exact memory address of the data item (the low-order bits of the address are in byte 2, the high-order bits in byte 3).
- Register — The instruction specifies the register or register pair in which the data is located.
- Register Indirect — The instruction specifies a register pair which contains the memory address where the data is located (the high-order bits of the address are in the first register of the pair the low-order bits in the second).
- Immediate — The instruction contains the data itself. This is either an 8-bit quantity or a 16-bit quantity (least significant byte first, most significant byte second).

Unless directed by an interrupt or branch institution, the execution of instructions proceeds through consecutively increasing memory locations. A branch instruction can specify the address of the next instruction to be executed in one of two ways:

- Direct — The branch instruction contains the address of the next instruction to be executed. (Except for the 'RST' instruction, byte 2 contains the low-order address and byte 3 the high-order address.)
- Register Indirect — The branch instruction indicates a register-pair which contains the address of the next instruction to be executed. (The high-order bits of the address are in the first register of the pair, the low-order bits in the second.)

The RST instruction is a special one-byte call instruction (usually used during interrupt sequences). RST includes a three-bit field; program control is transferred to the instruction whose address is eight times the contents of this three-bit field.

5.5 CONDITION FLAGS:

There are five condition flags associated with the execution of instructions on the 8085A. They are Zero, Sign, Parity, Carry, and Auxiliary Carry. Each is represented by a 1-bit register (or flip-flop) in the CPU. A flag is set by forcing the bit to 1; it is reset by forcing the bit to 0.

Unless indicated otherwise, when an instruction affects a flag, it affects it in the following manner:

Zero: If the result of an instruction has the value 0, this flag is set; otherwise it is reset.

Sign: If the most significant bit of the result of the operation has the value 1, this flag is set; otherwise it is reset.

Parity: If the modulo 2 sum of the bits of the result of the operation is 0, (i.e., if the result has even parity), this flag is set; otherwise it is reset (i.e., if the result has odd parity).

Carry: If the instruction resulted in a carry (from addition), or a borrow (from subtraction or a comparison) out of the high-order bit, this flag is set; otherwise it is reset.

Auxiliary Carry: If the instruction caused a carry out of bit 3 and into bit 4 of the resulting value, the auxiliary carry is set; otherwise it is reset. This flag is affected by single-precision additions, subtractions, increments, decrements, comparisons, and logical operations, but is principally used with additions and increments preceding a DAA (Decimal Adjust Accumulator) instruction.

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5.6 INSTRUCTION SET ENCYCLOPEDIA

In the ensuing dozen pages, the complete 8085A instruction set is described, grouped in order under five different functional headings, as follows:

1. **Data Transfer Group** — Moves data between registers or between memory locations and registers. Includes moves, loads, stores, and exchanges. (See below.)
2. **Arithmetic Group** — Adds, subtracts, increments, or decrements data in registers or memory. (See page 5-13.)
3. **Logic Group** — ANDs, ORs, XORs, compares, rotates, or complements data in registers or between memory and a register. (See page 5-16.)
4. **Branch Group** — Initiates conditional or unconditional jumps, calls, returns, and restarts. (See page 5-20.)
5. **Stack, I/O, and Machine Control Group** — Includes instructions for maintaining the stack, reading from input ports, writing to output ports, setting and reading interrupt masks, and setting and clearing flags. (See page 5-22.)

The formats described in the encyclopedia reflect the assembly language processed by Intel-supplied assembler, used with the Intellec® development systems.

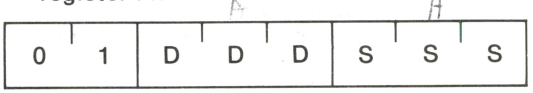
5.6.1 Data Transfer Group

This group of instructions transfers data to and from registers and memory. **Condition flags are not affected by any instruction in this group.**

MOV r1, r2 (Move Register)

(r1) ← (r2)

The content of register r2 is moved to register r1.

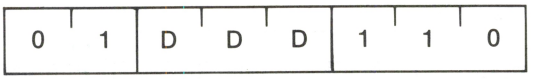


Cycles: 1
States: 4 (8085), 5 (8080)
Addressing: register
Flags: none

MOV r, M (Move from memory)

(r) ← ((H) (L))

The content of the memory location, whose address is in registers H and L, is moved to register r.

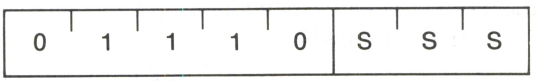


Cycles: 2
States: 7
Addressing: reg. indirect
Flags: none

MOV M, r (Move to memory)

((H)) (L)) ← (r)

The content of register r is moved to the memory location whose address is in registers H and L.

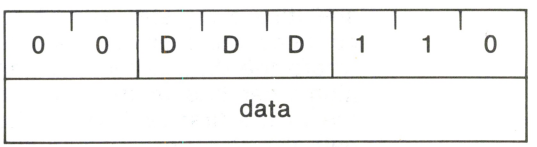


Cycles: 2
States: 7
Addressing: reg. indirect
Flags: none

MVI r, data (Move Immediate)

(r) ← (byte 2)

The content of byte 2 of the instruction is moved to register r.

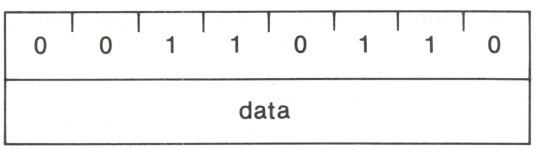


Cycles: 2
States: 7
Addressing: immediate
Flags: none

MVI M, data (Move to memory immediate)

((H) (L)) ← (byte 2)

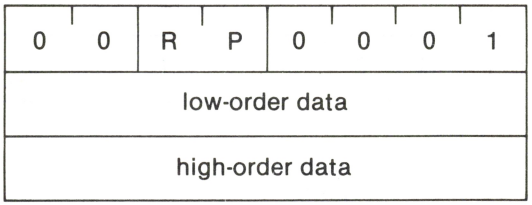
The content of byte 2 of the instruction is moved to the memory location whose address is in registers H and L.



Cycles: 3
States: 10
Addressing: immed./reg. indirect
Flags: none

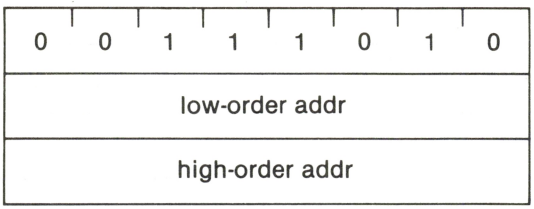
*All mnemonics copyrighted © Intel Corporation 1976.

LXI rp, data 16 (Load register pair immediate)
(rh) ← (byte 3),
(rl) ← (byte 2)
Byte 3 of the instruction is moved into the high-order register (rh) of the register pair rp. Byte 2 of the instruction is moved into the low-order register (rl) of the register pair rp.



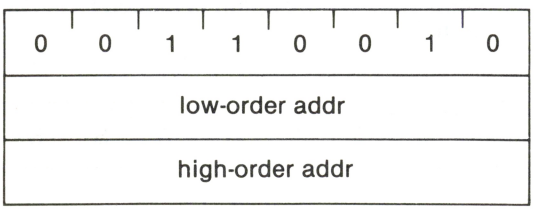
Cycles: 3
States: 10
Addressing: immediate
Flags: none

LDA addr (Load Accumulator direct)
(A) ← ((byte 3)(byte 2))
The content of the memory location, whose address is specified in byte 2 and byte 3 of the instruction, is moved to register A.



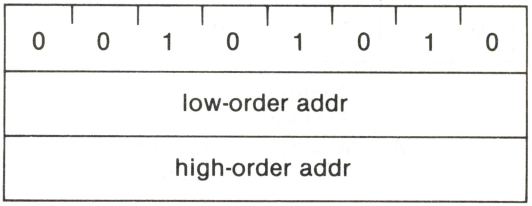
Cycles: 4
States: 13
Addressing: direct
Flags: none

STA addr (Store Accumulator direct)
((byte 3)(byte 2)) ← (A)
The content of the accumulator is moved to the memory location whose address is specified in byte 2 and byte 3 of the instruction.



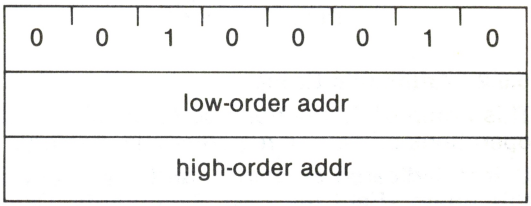
Cycles: 4
States: 13
Addressing: direct
Flags: none

LHLD addr (Load H and L direct)
(L)←((byte 3)(byte 2))
(H)←((byte 3)(byte 2)+1)
The content of the memory location, whose address is specified in byte 2 and byte 3 of the instruction, is moved to register L. The content of the memory location at the succeeding address is moved to register H.



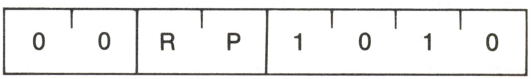
Cycles: 5
States: 16
Addressing: direct
Flags: none

SHLD addr (Store H and L direct)
((byte 3)(byte 2))←(L)
((byte 3)(byte 2)+1)←(H)
The content of register L is moved to the memory location whose address is specified in byte 2 and byte 3. The content of register H is moved to the succeeding memory location.



Cycles: 5
States: 16
Addressing: direct
Flags: none

LDAX rp (Load accumulator indirect)
(A) ← ((rp))
The content of the memory location, whose address is in the register pair rp, is moved to register A. Note: only register pairs rp = B (registers B and C) or rp = D (registers D and E) may be specified.



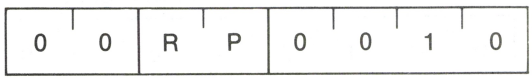
Cycles: 2
States: 7
Addressing: reg. indirect
Flags: none

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STAX rp (Store accumulator indirect)

((rp)) ← (A)

The content of register A is moved to the memory location whose address is in the register pair rp. Note: only register pairs rp = B (registers B and C) or rp = D (registers D and E) may be specified.

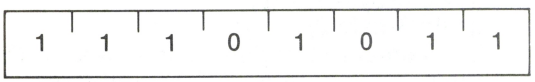


Cycles: 2
States: 7
Addressing: reg. indirect
Flags: none

XCHG (Exchange H and L with D and E)

(H) ↔ (D)
(L) ↔ (E)

The contents of registers H and L are exchanged with the contents of registers D and E.



Cycles: 1
States: 4
Addressing: register
Flags: none

5.6.2 Arithmetic Group

This group of instructions performs arithmetic operations on data in registers and memory.

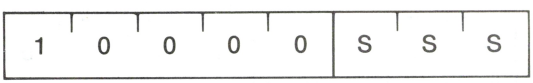
Unless indicated otherwise, all instructions in this group affect the Zero, Sign, Parity, Carry, and Auxiliary Carry flags according to the standard rules.

All subtraction operations are performed via two's complement arithmetic and set the carry flag to one to indicate a borrow and clear it to indicate no borrow.

ADD r (Add Register)

(A) ← (A) + (r)

The content of register r is added to the content of the accumulator. The result is placed in the accumulator.

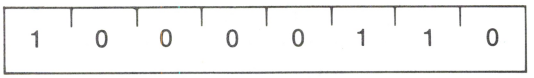


Cycles: 1
States: 4
Addressing: register
Flags: Z,S,P,CY,AC

ADD M (Add memory)

(A) ← (A) + ((H) (L))

The content of the memory location whose address is contained in the H and L registers is added to the content of the accumulator. The result is placed in the accumulator.

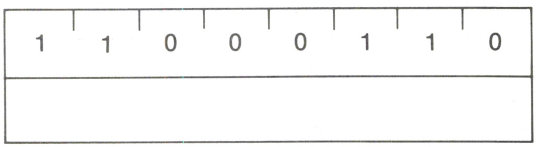


Cycles: 2
States: 7
Addressing: reg. indirect
Flags: Z,S,P,CY,AC

ADI data (Add immediate)

(A) ← (A) + (byte 2)

The content of the second byte of the instruction is added to the content of the accumulator. The result is placed in the accumulator.

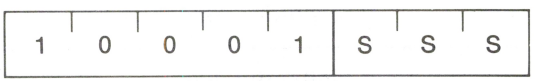


Cycles: 2
States: 7
Addressing: immediate
Flags: Z,S,P,CY,AC

ADC r (Add Register with carry)

(A) ← (A) + (r) + (CY)

The content of register r and the content of the carry bit are added to the content of the accumulator. The result is placed in the accumulator.



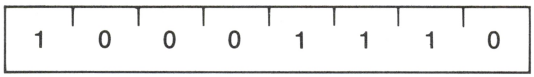
Cycles: 1
States: 4
Addressing: register
Flags: Z,S,P,CY,AC

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ADC M (Add memory with carry)

(A) ← (A) + ((H) (L)) + (CY)

The content of the memory location whose address is contained in the H and L registers and the content of the CY flag are added to the accumulator. The result is placed in the accumulator.

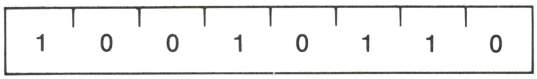


Cycles: 2
States: 7
Addressing: reg. indirect
Flags: Z,S,P,CY,AC

SUB M (Subtract memory)

(A) ← (A) − ((H) (L))

The content of the memory location whose address is contained in the H and L registers is subtracted from the content of the accumulator. The result is placed in the accumulator.

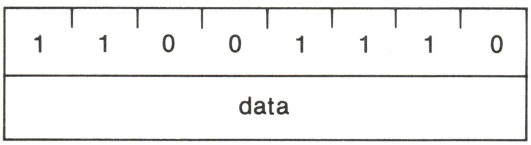


Cycles: 2
States: 7
Addressing: reg. indirect
Flags: Z,S,P,CY,AC

ACI data (Add immediate with carry)

(A) ← (A) + (byte 2) + (CY)

The content of the second byte of the instruction and the content of the CY flag are added to the contents of the accumulator. The result is placed in the accumulator.

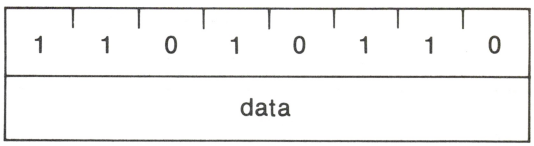


Cycles: 2
States: 7
Addressing: immediate
Flags: Z,S,P,CY,AC

SUI data (Subtract immediate)

(A) ← (A) − (byte 2)

The content of the second byte of the instruction is subtracted from the content of the accumulator. The result is placed in the accumulator.

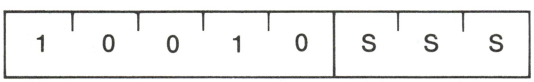


Cycles: 2
States: 7
Addressing: immediate
Flags: Z,S,P,CY,AC

SUB r (Subtract Register)

(A) ← (A) − (r)

The content of register r is subtracted from the content of the accumulator. The result is placed in the accumulator.

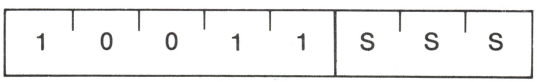


Cycles: 1
States: 4
Addressing: register
Flags: Z,S,P,CY,AC

SBB r (Subtract Register with borrow)

(A) ← (A) − (r) − (CY)

The content of register r and the content of the CY flag are both subtracted from the accumulator. The result is placed in the accumulator.



Cycles: 1
States: 4
Addressing: register
Flags: Z,S,P,CY,AC

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SBB M (Subtract memory with borrow)

(A) ← (A) − ((H) (L)) − (CY)

The content of the memory location whose address is contained in the H and L registers and the content of the CY flag are both subtracted from the accumulator. The result is placed in the accumulator.

1	0	0	1	1	1	1	0

Cycles: 2
States: 7
Addressing: reg. indirect
Flags: Z,S,P,CY,AC

SBI data (Subtract immediate with borrow)

(A) ← (A) − (byte 2) − (CY)

The contents of the second byte of the instruction and the contents of the CY flag are both subtracted from the accumulator. The result is placed in the accumulator.

1	1	0	1	1	1	1	0
data							

Cycles: 2
States: 7
Addressing: immediate
Flags: Z,S,P,CY,AC

INR r (Increment Register)

(r) ← (r) + 1

The content of register r is incremented by one. Note: All condition flags **except CY** are affected.

0	0	D	D	D	1	0	0

Cycles: 1
States: 4 (8085), 5 (8080)
Addressing: register
Flags: Z,S,P,AC

INR M (Increment memory)

((H) (L) ← ((H) (L)) + 1

The content of the memory location whose address is contained in the H and L registers is incremented by one. Note: All condition flags **except CY** are affected.

0	0	1	1	0	1	0	0

Cycles: 3
States: 10
Addressing: reg. indirect
Flags: Z,S,P,AC

DCR r (Decrement Register)

(r) ← (r) − 1

The content of register r is decremented by one. Note: All condition flags **except CY** are affected.

0	0	D	D	D	1	0	1

Cycles: 1
States: 4 (8085), 5 (8080)
Addressing: register
Flags: Z,S,P,AC

DCR M (Decrement memory)

((H) (L)) ← ((H) (L)) − 1

The content of the memory location whose address is contained in the H and L registers is decremented by one. Note: All condition flags **except CY** are affected.

0	0	1	1	0	1	0	1

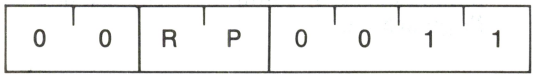
Cycles: 3
States: 10
Addressing: reg. indirect
Flags: Z,S,P,AC

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INX rp (Increment register pair)

(rh) (rl) ← (rh) (rl) + 1

The content of the register pair rp is incremented by one. Note: **No condition flags are affected.**

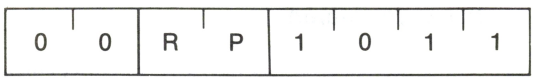


Cycles: 1
States: 6 (8085), 5 (8080)
Addressing: register
Flags: none

DCX rp (Decrement register pair)

(rh) (rl) ← (rh) (rl) − 1

The content of the register pair rp is decremented by one. Note: **No condition flags are affected.**

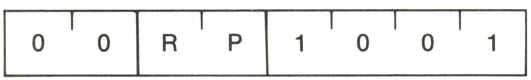


Cycles: 1
States: 6 (8085), 5 (8080)
Addressing: register
Flags: none

DAD rp (Add register pair to H and L)

(H) (L) ← (H) (L) + (rh) (rl)

The content of the register pair rp is added to the content of the register pair H and L. The result is placed in the register pair H and L. Note: **Only the CY flag is affected.** It is set if there is a carry out of the double precision add; otherwise it is reset.



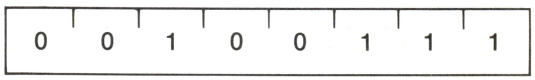
Cycles: 3
States: 10
Addressing: register
Flags: CY

DAA (Decimal Adjust Accumulator)

The eight-bit number in the accumulator is adjusted to form two four-bit Binary-Coded-Decimal digits by the following process:

1. If the value of the lease significant 4 bits of the accumulator is greater than 9 **or** if the AC flag is set, 6 is added to the accumulator.
2. If the value of the most significant 4 bits of the accumulator is now greater than 9, **or** if the CY flag is set, 6 is added to the most significant 4 bits of the accumulator.

NOTE: All flags are affected.



Cycles: 1
States: 4
Flags: Z,S,P,CY,AC

5.6.3 Logical Group

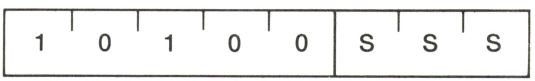
This group of instructions performs logical (Boolean) operations on data in registers and memory and on condition flags.

Unless indicated otherwise, all instructions in this group affect the Zero, Sign, Parity, Auxiliary Carry, and Carry flags according to the standard rules.

ANA r (AND Register)

(A) ← (A) ∧ (r)

The content of register r is logically ANDed with the content of the accumulator. The result is placed in the accumulator. **The CY flag is cleared and AC is set (8085). The CY flag is cleared and AC is set to the OR'ing of bits 3 of the operands (8080).**



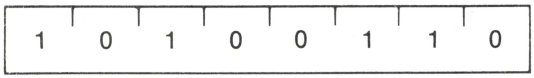
Cycles: 1
States: 4
Addressing: register
Flags: Z,S,P,CY,AC

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ANA M (AND memory)

(A) ← (A) ∧ ((H) (L))

The contents of the memory location whose address is contained in the H and L registers is logically ANDed with the content of the accumulator. The result is placed in the accumulator. **The CY flag is cleared and AC is set (8085). The CY flag is cleared and AC is set to the OR'ing of bits 3 of the operands (8080).**

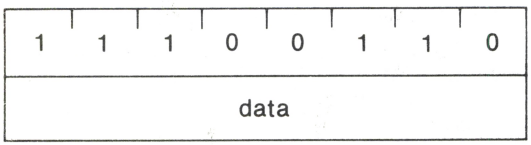


Cycles: 2
States: 7
Addressing: reg. indirect
Flags: Z,S,P,CY,AC

ANI data (AND immediate)

(A) ← (A) ∧ (byte 2)

The content of the second byte of the instruction is logically ANDed with the contents of the accumulator. The result is placed in the accumulator. **The CY flag is cleared and AC is set (8085). The CY flag is cleared and AC is set to the OR'ing of bits 3 of the operands (8080).**

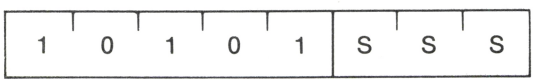


Cycles: 2
States: 7
Addressing: immediate
Flags: Z,S,P,CY,AC

XRA r (Exclusive OR Register)

(A) ← (A) ⊻ (r)

The content of register r is exclusive-OR'd with the content of the accumulator. The result is placed in the accumulator. **The CY and AC flags are cleared.**

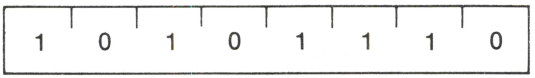


Cycles: 1
States: 4
Addressing: register
Flags: Z,S,P,CY,AC

XRA M (Exclusive OR Memory)

(A) ← (A) ⊻ ((H) (L))

The content of the memory location whose address is contained in the H and L registers is exclusive-OR'd with the content of the accumulator. The result is placed in the accumulator. **The CY and AC flags are cleared.**

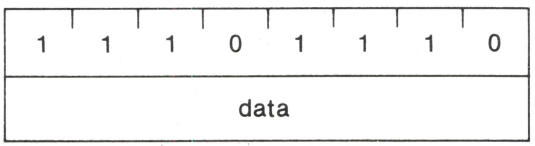


Cycles: 2
States: 7
Addressing: reg. indirect
Flags: Z,S,P,CY,AC

XRI data (Exclusive OR immediate)

(A) ← (A) ⊻ (byte 2)

The content of the second byte of the instruction is exclusive-OR'd with the content of the accumulator. The result is placed in the accumulator. **The CY and AC flags are cleared.**

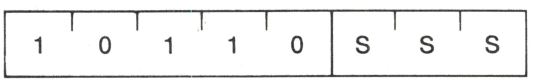


Cycles: 2
States: 7
Addressing: immediate
Flags: Z,S,P,CY,AC

ORA r (OR Register)

(A) ← (A) V (r)

The content of register r is inclusive-OR'd with the content of the accumulator. The result is placed in the accumulator. **The CY and AC flags are cleared.**



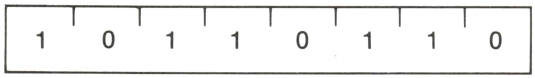
Cycles: 1
States: 4
Addressing: register
Flags: Z,S,P,CY,AC

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ORA M (OR memory)

(A) ← (A) V ((H) (L))

The content of the memory location whose address is contained in the H and L registers is inclusive-OR'd with the content of the accumulator. The result is placed in the accumulator. **The CY and AC flags are cleared.**

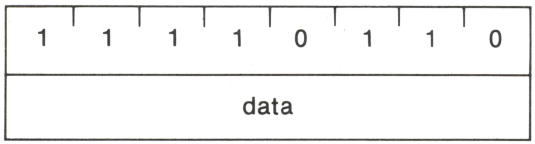


Cycles: 2
States: 7
Addressing: reg. indirect
Flags: Z,S,P,CY,AC

ORI data (OR Immediate)

(A) ← (A) V (byte 2)

The content of the second byte of the instruction is inclusive-OR'd with the content of the accumulator. The result is placed in the accumulator. **The CY and AC flags are cleared.**.

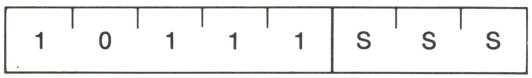


Cycles: 2
States: 7
Addressing: immediate
Flags: Z,S,P,CY,AC

CMP r (Compare Register)

(A) − (r)

The content of register r is subtracted from the accumulator. The accumulator remains unchanged. The condition flags are set as a result of the subtraction. **The Z flag is set to 1 if (A) = (r). The CY flag is set to 1 if (A) < (r).**

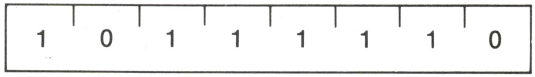


Cycles: 1
States: 4
Addressing: register
Flags: Z,S,P,CY,AC

CMP M (Compare memory)

(A) − ((H) (L))

The content of the memory location whose address is contained in the H and L registers is subtracted from the accumulator. The accumulator remains unchanged. The condition flags are set as a result of the subtraction. **The Z flag is set to 1 if (A)=((H) (L)). The CY flag is set to 1 if (A)<((H) (L)).**

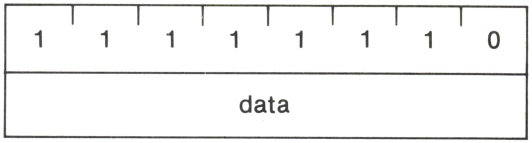


Cycles: 2
States: 7
Addressing: reg. indirect
Flags: Z,S,P,CY,AC

CPI data (Compare immediate)

(A) − (byte 2)

The content of the second byte of the instruction is subtracted from the accumulator. The condition flags are set by the result of the subtraction. **The Z flag is set to 1 if (A)=(byte 2). The CY flag is set to 1 if (A)<(byte 2).**



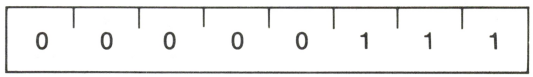
Cycles: 2
States: 7
Addressing: immediate
Flags: Z,S,P,CY,AC

RLC (Rotate left)

$(A_{n+1}) \leftarrow (A_n)$;$(A_0) \leftarrow (A_7)$

$(CY) \leftarrow (A_7)$

The content of the accumulator is rotated left one position. The low order bit and the CY flag are both set to the value shifted out of the high order bit position. **Only the CY flag is affected.**



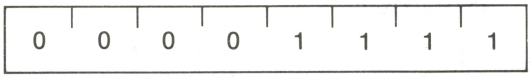
Cycles: 1
States: 4
Flags: CY

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RRC (Rotate right)

$(A_n) \leftarrow (A_{n+1})$; $(A_7) \leftarrow (A_0)$
$(CY) \leftarrow (A_0)$

The content of the accumulator is rotated right one position. The high order bit and the CY flag are both set to the value shifted out of the low order bit position. **Only the CY flag is affected.**

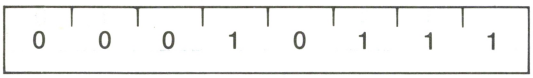


Cycles: 1
States: 4
Flags: CY

RAL (Rotate left through carry)

$(A_{n+1}) \leftarrow (A_n)$; $(CY) \leftarrow (A_7)$
$(A_0) \leftarrow (CY)$

The content of the accumulator is rotated left one position through the CY flag. The low order bit is set equal to the CY flag and the CY flag is set to the value shifted out of the high order bit. **Only the CY flag is affected.**

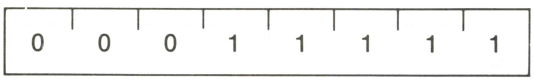


Cycles: 1
States: 4
Flags: CY

RAR (Rotate right through carry)

$(A_n) \leftarrow (A_{n+1})$;$(CY) \leftarrow (A_0)$
$(A_7) \leftarrow (CY)$

The content of the accumulator is rotated right one position through the CY flag. The high order bit is set to the CY flag and the CY flag is set to the value shifted out of the low order bit. **Only the CY flag is affected.**

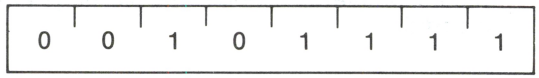


Cycles: 1
States: 4
Flags: CY

CMA (Complement accumulator)

$(A) \leftarrow (\overline{A})$

The contents of the accumulator are complemented (zero bits become 1, one bits become 0). **No flags are affected.**

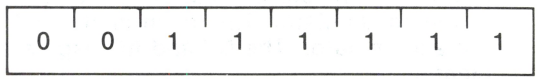


Cycles: 1
States: 4
Flags: none

CMC (Complement carry)

$(CY) \leftarrow (\overline{CY})$

The CY flag is complemented. **No other flags are affected.**

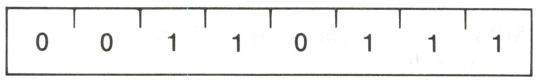


Cycles: 1
States: 4
Flags: CY

STC (Set carry)

$(CY) \leftarrow 1$

The CY flag is set to 1. **No other flags are affected.**



Cycles: 1
States: 4
Flags: CY

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5.6.4 Branch Group

This group of instructions alter normal sequential program flow.

Condition flags are not affected by any instruction in this group.

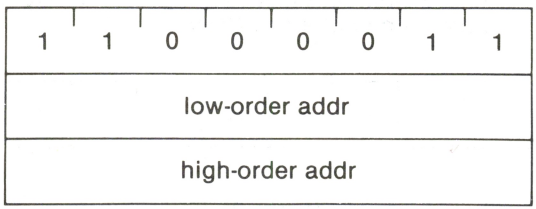
The two types of branch instructions are unconditional and conditional. Unconditional transfers simply perform the specified operation on register PC (the program counter). Conditional transfers examine the status of one of the four processor flags to determine if the specified branch is to be executed. The conditions that may be specified are as follows:

CONDITION	CCC
NZ — not zero (Z = 0)	000
Z — zero (Z = 1)	001
NC — no carry (CY = 0)	010
C — carry (CY = 1)	011
PO — parity odd (P = 0)	100
PE — parity even (P = 1)	101
P — plus (S = 0)	110
M — minus (S = 1)	111

JMP addr (Jump)

(PC) ← (byte 3) (byte 2)

Control is transferred to the instruction whose address is specified in byte 3 and byte 2 of the current instruction.



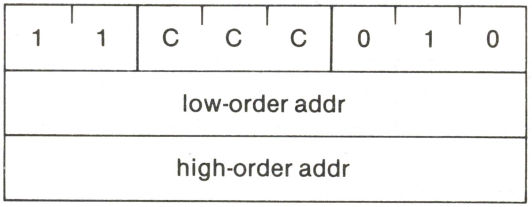
Cycles: 3
States: 10
Addressing: immediate
Flags: none

Jcondition addr (Conditional jump)

If (CCC),

(PC) ← (byte 3) (byte 2)

If the specified condition is true, control is transferred to the instruction whose address is specified in byte 3 and byte 2 of the current instruciton; otherwise, control continues sequentially.



Cycles: 2/3 (8085), 3 (8080)
States: 7/10 (8085), 10 (8080)
Addressing: immediate
Flags: none

CALL addr (Call)

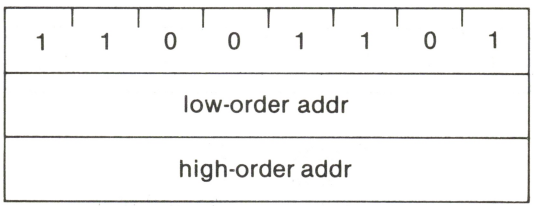
((SP) − 1) ← (PCH)

((SP) − 2) ← (PCL)

(SP) ← (SP) − 2

(PC) ← (byte 3) (byte 2)

The high-order eight bits of the next instruction address are moved to the memory location whose address is one less than the content of register SP. The low-order eight bits of the next instruction address are moved to the memory location whose address is two less than the content of register SP. The content of register SP is decremented by 2. Control is transferred to the instruction whose address is specified in byte 3 and byte 2 of the current instruction.

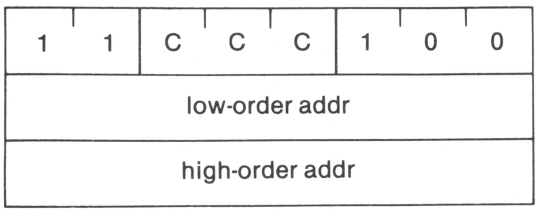


Cycles: 5
States: 18 (8085), 17 (8080)
Addressing: immediate/ reg. indirect
Flags: none

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Ccondition addr (Condition call)

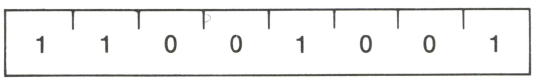
If (CCC),
((SP) − 1) ← (PCH)
((SP) − 2) ← (PCL)
(SP) ← (SP) − 2
(PC) ← (byte 3) (byte 2)
If the specified condition is true, the actions specified in the CALL instruction (see above) are performed; otherwise, control continues sequentially.



Cycles: 2/5 (8085), 3/5 (8080)
States: 9/18 (8085), 11/17 (8080)
Addressing: immediate/ reg. indirect
Flags: none

RET (Return)

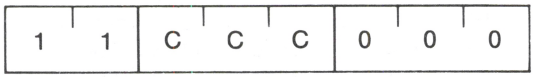
(PCL) ← ((SP));
(PCH) ← ((SP) + 1);
(SP) ← (SP) + 2;
The content of the memory location whose address is specified in register SP is moved to the low-order eight bits of register PC. The content of the memory location whose address is one more than the content of register SP is moved to the high-order eight bits of register PC. The content of register SP is incremented by 2.



Cycles: 3
States: 10
Addressing: reg. indirect
Flags: none

Rcondition (Conditional return)

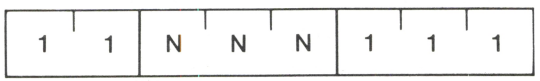
If (CCC),
(PCL) ← ((SP))
(PCH) ← ((SP) + 1)
(SP) ← (SP) + 2
If the specified condition is true, the actions specified in the RET instruction (see above) are performed; otherwise, control continues sequentially.



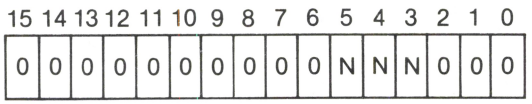
Cycles: 1/3
States: 6/12 (8085), 5/11 (8080)
Addressing: reg. indirect
Flags: none

RST n (Restart)

((SP) − 1) ← (PCH)
((SP) − 2) ← (PCL)
(SP) ← (SP) − 2
(PC) ← 8 * (NNN)
The high-order eight bits of the next instruction address are moved to the memory location whose address is one less than the content of register SP. The low-order eight bits of the next instruction address are moved to the memory location whose address is two less than the content of register SP. The content of register SP is decremented by two. Control is transferred to the instruction whose address is eight times the content of NNN.



Cycles: 3
States: 12 (8085), 11 (8080)
Addressing: reg. indirect
Flags: none



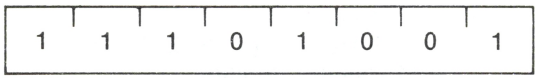
Program Counter After Restart

*All mnemonics copyrighted © Intel Corporation 1976.

PCHL (Jump H and L indirect — move H and L to PC)

(PCH) ← (H)
(PCL) ← (L)

The content of register H is moved to the high-order eight bits of register PC. The content of register L is moved to the low-order eight bits of register PC.



Cycles: 1
States: 6 (8085), 5 (8080)
Addressing: register
Flags: none

5.6.5 Stack, I/O, and Machine Control Group

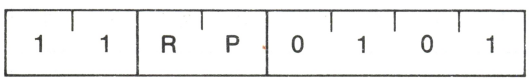
This group of instructions performs I/O, manipulates the Stack, and alters internal control flags.

Unless otherwise specified, **condition flags are not affected by any instructions in this group.**

PUSH rp (Push)

((SP) − 1) ← (rh)
((SP) − 2) ← (rl)
((SP) ← (SP) − 2

The content of the high-order register of register pair rp is moved to the memory location whose address is one less than the content of register SP. The content of the low-order register of register pair rp is moved to the memory location whose address is two less than the content of register SP. The content of register SP is decremented by 2. **Note: Register pair rp = SP may not be specified.**

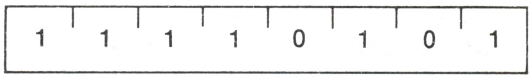


Cycles: 3
States: 12 (8085), 11 (8080)
Addressing: reg. indirect
Flags: none

PUSH PSW (Push processor status word)

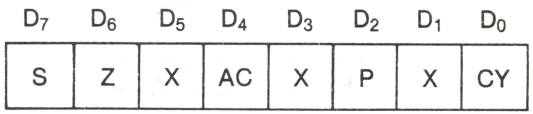
((SP) − 1) ← (A)
((SP) − $2)_0$ ← (CY), ((SP) − $2)_1$ ← X
((SP) − $2)_2$ ← (P), ((SP) − $2)_3$ ← X
((SP) − $2)_4$ ← (AC), ((SP) − $2)_5$ ← X
((SP) − $2)_6$ ← (Z), ((SP) − $2)_7$ ← (S)
(SP) ← (SP) − 2 X: Undefined.

The content of register A is moved to the memory location whose address is one less than register SP. The contents of the condition flags are assembled into a processor status word and the word is moved to the memory location whose address is two less than the content of register SP. The content of register SP is decremented by two.



Cycles: 3
States: 12 (8085), 11 (8080)
Addressing: reg. indirect
Flags: none

FLAG WORD

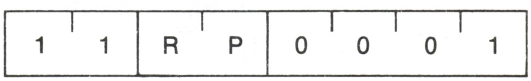


X: undefined

POP rp (Pop)

(rl) ← ((SP))
(rh) ← ((SP) + 1)
(SP) ← (SP) + 2

The content of the memory location, whose address is specified by the content of register SP, is moved to the low-order register of register pair rp. The content of the memory location, whose address is one more than the content of register SP, is moved to the high-order register of register rp. The content of register SP is incremented by 2. **Note: Register pair rp = SP may not be specified.**



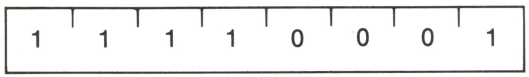
Cycles: 3
States: 10
Addressing: reg.indirect
Flags: none

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POP PSW (Pop processor status word)

(CY) ← ((SP))$_0$
(P)← ((SP))$_2$
(AC)← ((SP))$_4$
(Z) ← ((SP))$_6$
(S) ← ((SP))$_7$
(A) ← ((SP) + 1)
(SP) ← (SP) + 2

The content of the memory location whose address is specified by the content of register SP is used to restore the condition flags. The content of the memory location whose address is one more than the content of register SP is moved to register A. The content of register SP is incremented by 2.

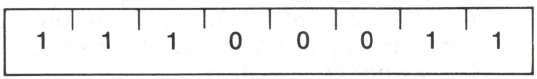


Cycles: 3
States: 10
Addressing: reg. indirect
Flags: Z,S,P,CY,AC

XTHL (Exchange stack top with H and L)

(L) ↔ ((SP))
(H) ↔ ((SP) + 1)

The content of the L register is exchanged with the content of the memory location whose address is specified by the content of register SP. The content of the H register is exchanged with the content of the memory location whose address is one more than the content of register SP.

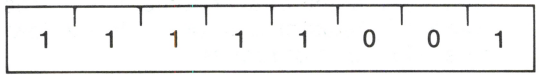


Cycles: 5
States: 16 (8085), 18 (8080)
Addressing: reg. indirect
Flags: none

SPHL (Move HL to SP)

(SP) ← (H) (L)

The contents of registers H and L (16 bits) are moved to register SP.

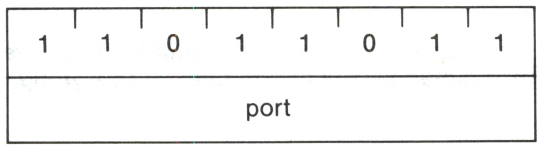


Cycles: 1
States: 6 (8085), 5 (8080)
Addressing: register
Flags: none

IN port (Input)

(A)←(data)

The data placed on the eight bit bi-directional data bus by the specified port is moved to register A.

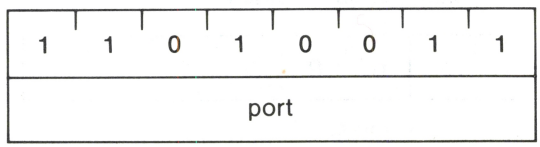


Cycles: 3
States: 10
Addressing: direct
Flags: none

OUT port (Output)

(data) ← (A)

The content of register A is placed on the eight bit bi-directional data bus for transmission to the specified port.



Cycles: 3
States: 10
Addressing: direct
Flags: none

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EI (Enable interrupts)

The interrupt system is enabled **following the execution of the next instruction. Interrupts are not recognized during the EI instruction.**

1	1	1	1	1	0	1	1

Cycles: 1
States: 4
Flags: none

NOTE: Placing an EI instruction on the bus in response to $\overline{INTA}$ during an INA cycle is prohibited. (8085)

DI (Disable interrupts)

The interrupt system is disabled **immediately following the execution of the DI instruction. Interrupts are not recognized during the DI instruction.**

1	1	1	1	0	0	1	1

Cycles: 1
States: 4
Flags: none

NOTE: Placing a DI instruction on the bus in response to $\overline{INTA}$ during an INA cycle is prohibited. (8085)

HLT (Halt)

The processor is stopped. The registers and flags are unaffected. (8080) A second ALE is generated during the execution of HLT to strobe out the Halt cycle status information. (8085)

0	1	1	1	0	1	1	0

Cycles: 1 + (8085), 1 (8080)
States: 5 (8085), 7 (8080)
Flags: none

NOP (No op)

No operation is performed. The registers and flags are unaffected.

0	0	0	0	0	0	0	0

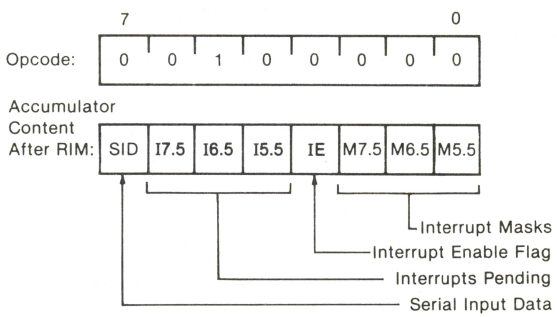
Cycles: 1
States: 4
Flags: none

RIM (Read Interrupt Masks) (8085 only)

The RIM instruction loads data into the accumulator relating to interrupts and the serial input. This data contains the following information:

- Current interrupt mask status for the RST 5.5, 6.5, and 7.5 hardware interrupts (1 = mask disabled)
- Current interrupt enable flag status (1 = interrupts enabled) except immediately following a TRAP interrupt. (See below.)
- Hardware interrupts pending (i.e., signal received but not yet serviced), on the RST 5.5, 6.5, and 7.5 lines.
- Serial input data.

Immediately following a TRAP interrupt, the RIM instruction must be executed as a part of the service routine if you need to retrieve current interrupt status later. Bit 3 of the accumulator is (in this special case only) loaded with the interrupt enable (IE) flag status that existed prior to the TRAP interrupt. Following an RST 5.5, 6.5, 7.5, or INTR interrupt, the interrupt flag flip-flop reflects the current interrupt enable status. Bit 6 of the accumulator (I7.5) is loaded with the status of the RST 7.5 flip-flop, which is always set (edge-triggered) by an input on the RST 7.5 input line, even when that interrupt has been previously masked. (See SIM Instruction.)



Cycles: 1
States: 4
Flags: none

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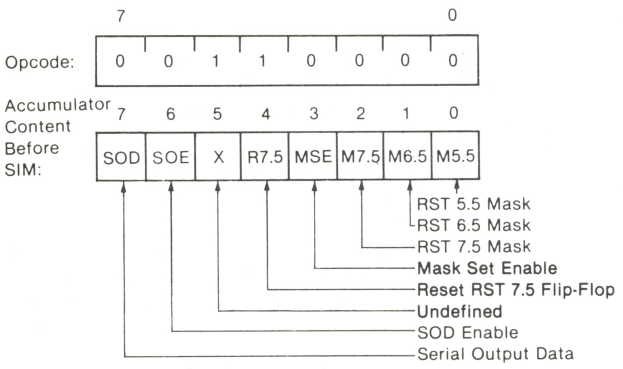
SIM (Set Interrupt Masks) (8085 only)

The execution of the SIM instruction uses the contents of the accumulator (which must be previously loaded) to perform the following functions:

- Program the interrupt mask for the RST 5.5, 6.5, and 7.5 hardware interrupts.
- Reset the edge-triggered RST 7.5 input latch.
- Load the SOD output latch.

To program the interrupt masks, first set accumulator bit 3 to 1 and set to 1 any bits 0, 1, and 2, which disable interrupts RST 5.5, 6.5, and 7.5, respectively. Then do a SIM instruction. If accumulator bit 3 is 0 when the SIM instruction is executed, the interrupt mask register will not change. If accumulator bit 4 is 1 when the SIM instruction is executed, the RST 7.5 latch is then reset. RST 7.5 is distinguished by the fact that its latch is always set by a rising edge on the RST 7.5 input pin, even if the jump to service routine is inhibited by masking. This latch remains high until cleared by a $\overline{\text{RESET IN}}$, by a SIM Instruction with accumulator bit 4 high, or by an internal processor acknowledge to an RST 7.5 interrupt subsequent to the removal of the mask (by a SIM instruction). The $\overline{\text{RESET IN}}$ signal always sets all three RST mask bits.

If accumulator bit 6 is at the 1 level when the SIM instruction is executed, the state of accumulator bit 7 is loaded into the SOD latch and thus becomes available for interface to an external device. The SOD latch is unaffected by the SIM instruction if bit 6 is 0. SOD is always reset by the $\overline{\text{RESET IN}}$ signal.



Cycles: 1
States: 4
Flags: none

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8080A/8085A INSTRUCTION SET INDEX
Table 5-1

Instruction		Code	Bytes	T States		Machine Cycles
				8085A	8080A	
ACI	DATA	CE data	2	7	7	F R
ADC	REG	1000 1SSS	1	4	4	F
ADC	M	8E	1	7	7	F R
ADD	REG	1000 0SSS	1	4	4	F
ADD	M	86	1	7	7	F R
ADI	DATA	C6 data	2	7	7	F R
ANA	REG	1010 0SSS	1	4	4	F
ANA	M	A6	1	7	7	F R
ANI	DATA	E6 data	2	7	7	F R
CALL	LABEL	CD addr	3	18	17	S R R W W*
CC	LABEL	DC addr	3	9/18	11/17	S R•/S R R W W*
CM	LABEL	FC addr	3	9/18	11/17	S R•/S R R W W*
CMA		2F	1	4	4	F
CMC		3F	1	4	4	F
CMP	REG	1011 1SSS	1	4	4	F
CMP	M	BE	1	7	7	F R
CNC	LABEL	D4 addr	3	9/18	11/17	S R•/S R R W W*
CNZ	LABEL	C4 addr	3	9/18	11/17	S R•/S R R W W*
CP	LABEL	F4 addr	3	9/18	11/17	S R•/S R R W W*
CPE	LABEL	EC addr	3	9/18	11/17	S R•/S R R W W*
CPI	DATA	FE data	2	7	7	F R
CPO	LABEL	E4 addr	3	9/18	11/17	S R•/S R R W W*
CZ	LABEL	CC addr	3	9/18	11/17	S R•/S R R W W*
DAA		27	1	4	4	F
DAD	RP	00RP 1001	1	10	10	F B B
DCR	REG	00SS S101	1	4	5	F*
DCR	M	35	1	10	10	F R W
DCX	RP	00RP 1011	1	6	5	S*
DI		F3	1	4	4	F
EI		FB	1	4	4	F
HLT		76	1	5	7	F B
IN	PORT	DB data	2	10	10	F R I
INR	REG	00SS S100	1	4	5	F*
INR	M	34	1	10	10	F R W
INX	RP	00RP 0011	1	6	5	S*
JC	LABEL	DA addr	3	7/10	10	F R/F R R†
JM	LABEL	FA addr	3	7/10	10	F R/F R R†
JMP	LABEL	C3 addr	3	10	10	F R R
JNC	LABEL	D2 addr	3	7/10	10	F R/F R R†
JNZ	LABEL	C2 addr	3	7/10	10	F R/F R R†
JP	LABEL	F2 addr	3	7/10	10	F R/F R R†
JPE	LABEL	EA addr	3	7/10	10	F R/F R R†
JPO	LABEL	E2 addr	3	7/10	10	F R/F R R†
JZ	LABEL	CA addr	3	7/10	10	F R/F R R†
LDA	ADDR	3A addr	3	13	13	F R R R
LDAX	RP	000X 1010	1	7	7	F R
LHLD	ADDR	2A addr	3	16	16	F R R R R

Instruction		Code	Bytes	T States		Machine Cycles
				8085A	8080A	
LXI	RP,DATA16	00RP 0001 data16	3	10	10	F R R
MOV	REG,REG	01DD DSSS	1	4	5	F*
MOV	M,REG	0111 0SSS	1	7	7	F W
MOV	REG,M	01DD D110	1	7	7	F R
MVI	REG,DATA	00DD D110 data	2	7	7	F R
MVI	M,DATA	36 data	2	10	10	F R W
NOP		00	1	4	4	F
ORA	REG	1011 0SSS	1	4	4	F
ORA	M	B6	1	7	7	F R
ORI	DATA	F6 data	2	7	7	F R
OUT	PORT	D3 data	2	10	10	F R O
PCHL		E9	1	6	5	S*
POP	RP	11RP 0001	1	10	10	F R R
PUSH	RP	11RP 0101	1	12	11	S W W*
RAL		17	1	4	4	F
RAR		1F	1	4	4	F
RC		D8	1	6/12	5/11	S/S R R*
RET		C9	1	10	10	F R R
RIM (8085A only)		20	1	4	–	F
RLC		07	1	4	4	F
RM		F8	1	6/12	5/11	S/S R R*
RNC		D0	1	6/12	5/11	S/S R R*
RNZ		C0	1	6/12	5/11	S/S R R*
RP		F0	1	6/12	5/11	S/S R R*
RPE		E8	1	6/12	5/11	S/S R R*
RPO		E0	1	6/12	5/11	S/S R R*
RRC		0F	1	4	4	F
RST	N	11XX X111	1	12	11	S W W*
RZ		C8	1	6/12	5/11	S/S R R*
SBB	REG	1001 1SSS	1	4	4	F
SBB	M	9E	1	7	7	F R
SBI	DATA	DE data	2	7	7	F R
SHLD	ADDR	22 addr	3	16	16	F R R W W
SIM (8085A only)		30	1	4	–	F
SPHL		F9	1	6	5	S*
STA	ADDR	32 addr	3	13	13	F R R W
STAX	RP	000X 0010	1	7	7	F W
STC		37	1	4	4	F
SUB	REG	1001 0SSS	1	4	4	F
SUB	M	96	1	7	7	F R
SUI	DATA	D6 data	2	7	7	F R
XCHG		EB	1	4	4	F
XRA	REG	1010 1SSS	1	4	4	F
XRA	M	AE	1	7	7	F R
XRI	DATA	EE data	2	7	7	F R
XTHL		E3	1	16	18	F R R W W

Machine cycle types:

F	Four clock period instr fetch
S	Six clock period instr fetch
R	Memory read
I	I/O read
W	Memory write
O	I/O write
B	Bus idle
X	Variable or optional binary digit
DDD	Binary digits identifying a destination register — B = 000, C = 001, D = 010 Memory = 110
SSS	Binary digits identifying a source register — E = 011, H = 100, L = 101 A = 111
RP	Register Pair — BC = 00, HL = 10; DE = 01, SP = 11

*Five clock period instruction fetch with 8080A.

†The longer machine cycle sequence applies regardless of condition evaluation with 8080A.

•An extra READ cycle (R) will occur for this condition with 8080A.

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8085A CPU INSTRUCTIONS IN OPERATION CODE SEQUENCE
Table 5-2

OP CODE	MNEMONIC	OP CODE	MNEMONIC	OP CODE	MNEMONIC	OP CODE	MNEMONIC	OP CODE	MNEMONIC	OP CODE	MNEMONIC
00	NOP	2B	DCX H	56	MOV D,M	81	ADD C	AC	XRA H	D7	RST 2
01	LXI B,D16	2C	INR L	57	MOV D,A	82	ADD D	AD	XRA L	D8	RC
02	STAX B	2D	DCR L	58	MOV E,B	83	ADD E	AE	XRA M	D9	–
03	INX B	2E	MVI L,D8	59	MOV E,C	84	ADD H	AF	XRA A	DA	JC Adr
04	INR B	2F	CMA	5A	MOV E,D	85	ADD L	B0	ORA B	DB	IN D8
05	DCR B	30	SIM	5B	MOV E,E	86	ADD M	B1	ORA C	DC	CC Adr
06	MVI B,D8	31	LXI SP,D16	5C	MOV E,H	87	ADD A	B2	ORA D	DD	–
07	RLC	32	STA Adr	5D	MOV E,L	88	ADC B	B3	ORA E	DE	SBI D8
08	–	33	INX SP	5E	MOV E,M	89	ADC C	B4	ORA H	DF	RST 3
09	DAD B	34	INR M	5F	MOV E,A	8A	ADC D	B5	ORA L	E0	RPO
0A	LDAX B	35	DCR M	60	MOV H,B	8B	ADC E	B6	ORA M	E1	POP H
0B	DCX B	36	MVI M,D8	61	MOV H,C	8C	ADC H	B7	ORA A	E2	JPO Adr
0C	INR C	37	STC	62	MOV H,D	8D	ADC L	B8	CMP B	E3	XTHL
0D	DCR C	38	–	63	MOV H,E	8E	ADC M	B9	CMP C	E4	CPO Adr
0E	MVI C,D8	39	DAD SP	64	MOV H,H	8F	ADC A	BA	CMP D	E5	PUSH H
0F	RRC	3A	LDA Adr	65	MOV H,L	90	SUB B	BB	CMP E	E6	ANI D8
10	–	3B	DCX SP	66	MOV H,M	91	SUB C	BC	CMP H	E7	RST 4
11	LXI D,D16	3C	INR A	67	MOV H,A	92	SUB D	BD	CMP L	E8	RPE
12	STAX D	3D	DCR A	68	MOV L,B	93	SUB E	BE	CMP M	E9	PCHL
13	INX D	3E	MVI A,D8	69	MOV L,C	94	SUB H	BF	CMP A	EA	JPE Adr
14	INR D	3F	CMC	6A	MOV L,D	95	SUB L	C0	RNZ	EB	XCHG
15	DCR D	40	MOV B,B	6B	MOV L,E	96	SUB M	C1	POP B	EC	CPE Adr
16	MVI D,D8	41	MOV B,C	6C	MOV L,H	97	SUB A	C2	JNZ Adr	ED	–
17	RAL	42	MOV B,D	6D	MOV L,L	98	SBB B	C3	JMP Adr	EE	XRI D8
18	–	43	MOV B,E	6E	MOV L,M	99	SBB C	C4	CNZ Adr	EF	RST 5
19	DAD D	44	MOV B,H	6F	MOV L,A	9A	SBB D	C5	PUSH B	F0	RP
1A	LDAX D	45	MOV B,L	70	MOV M,B	9B	SBB E	C6	ADI D8	F1	POP PSW
1B	DCX D	46	MOV B,M	71	MOV M,C	9C	SBB H	C7	RST 0	F2	JP Adr
1C	INR E	47	MOV B,A	72	MOV M,D	9D	SBB L	C8	RZ	F3	DI
1D	DCR E	48	MOV C,B	73	MOV M,E	9E	SBB M	C9	RET Adr	F4	CP Adr
1E	MVI E,D8	49	MOV C,C	74	MOV M,H	9F	SBB A	CA	JZ	F5	PUSH PSW
1F	RAR	4A	MOV C,D	75	MOV M,L	A0	ANA B	CB	–	F6	ORI D8
20	RIM	4B	MOV C,E	76	HLT	A1	ANA C	CC	CZ Adr	F7	RST 6
21	LXI H,D16	4C	MOV C,H	77	MOV M,A	A2	ANA D	CD	CALL Adr	F8	RM
22	SHLD Adr	4D	MOV C,L	78	MOV A,B	A3	ANA E	CE	ACI D8	F9	SPHL
23	INX H	4E	MOV C,M	79	MOV A,C	A4	ANA H	CF	RST 1	FA	JM Adr
24	INR H	4F	MOV C,A	7A	MOV A,D	A5	ANA L	D0	RNC	FB	EI
25	DCR H	50	MOV D,B	7B	MOV A,E	A6	ANA M	D1	POP D	FC	CM Adr
26	MVI H,D8	51	MOV D,C	7C	MOV A,H	A7	ANA A	D2	JNC Adr	FD	–
27	DAA	52	MOV D,D	7D	MOV A,L	A8	XRA B	D3	OUT D8	FE	CPI D8
28	–	53	MOV D,E	7E	MOV A,M	A9	XRA C	D4	CNC Adr	FF	RST 7
29	DAD H	54	MOV D,H	7F	MOV A,A	AA	XRA D	D5	PUSH D		
2A	LHLD Adr	55	MOV D,L	80	ADD B	AB	XRA E	D6	SUI D8		

D8 = constant, or logical/arithmetic expression that evaluates to an 8-bit data quantity.

D16 = constant, or logical/arithmetic expression that evaluates to a 16-bit data quantity.

Adr = 16-bit address.

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8085A INSTRUCTION SET SUMMARY BY FUNCTIONAL GROUPING
Table 5-3

Mnemonic	Description	Instruction Code (1) D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	Page
MOVE, LOAD, AND STORE										
MOVr1 r2	Move register to register	0	1	D	D	D	S	S	S	5-4
MOV M,r	Move register to memory	0	1	1	1	0	S	S	S	5-4
MOV r,M	Move memory to register	0	1	D	D	D	1	1	0	5-4
MVI r	Move immediate register	0	0	D	D	D	1	1	0	5-4
MVI M	Move immediate memory	0	0	1	1	0	1	1	0	5-4
LXI B	Load immediate register Pair B & C	0	0	0	0	0	0	0	1	5-5
LXI D	Load immediate register Pair D & E	0	0	0	1	0	0	0	1	5-5
LXI H	Load immediate register Pair H & L	0	0	1	0	0	0	0	1	5-5
STAX B	Store A indirect	0	0	0	0	0	0	1	0	5-6
STAX D	Store A indirect	0	0	0	1	0	0	1	0	5-6
LDAX B	Load A indirect	0	0	0	0	1	0	1	0	5-5
LDAX D	Load A indirect	0	0	0	1	1	0	1	0	5-5
STA	Store A direct	0	0	1	1	0	0	1	0	5-5
LDA	Load A direct	0	0	1	1	1	0	1	0	5-5
SHLD	Store H & L direct	0	0	1	0	0	0	1	0	5-5
LHLD	Load H & L direct	0	0	1	0	1	0	1	0	5-5
XCHG	Exchange D & E, H & L Registers	1	1	1	0	1	0	1	1	5-6
STACK OPS										
PUSH B	Push register Pair B & C on stack	1	1	0	0	0	1	0	1	5-15
PUSH D	Push register Pair D & E on stack	1	1	0	1	0	1	0	1	5-15
PUSH H	Push register Pair H & L on stack	1	1	1	0	0	1	0	1	5-15
PUSH PSW	Push A and Flags on stack	1	1	1	1	0	1	0	1	5-15
POP B	Pop register Pair B & C off stack	1	1	0	0	0	0	0	1	5-15
POP D	Pop register Pair D & E off stack	1	1	0	1	0	0	0	1	5-15
POP H	Pop register Pair H & L off stack	1	1	1	0	0	0	0	1	5-15
POP PSW	Pop A and Flags off stack	1	1	1	1	0	0	0	1	5-15
XTHL	Exchange top of stack, H & L	1	1	1	0	0	0	1	1	5-16
SPHL	H & L to stack pointer	1	1	1	1	1	0	0	1	5-16
LXI SP	Load immediate stack pointer	0	0	1	1	0	0	0	1	5-5
INX SP	Increment stack pointer	0	0	1	1	0	0	1	1	5-9
DCX SP	Decrement stack pointer	0	0	1	1	1	0	1	1	5-9
JUMP										
JMP	Jump unconditional	1	1	0	0	0	0	1	1	5-13
JC	Jump on carry	1	1	0	1	1	0	1	0	5-13
JNC	Jump on no carry	1	1	0	1	0	0	1	0	5-13
JZ	Jump on zero	1	1	0	0	1	0	1	0	5-13
JNZ	Jump on no zero	1	1	0	0	0	0	1	0	5-13
JP	Jump on positive	1	1	1	1	0	0	1	0	5-13
JM	Jump on minus	1	1	1	1	1	0	1	0	5-13
JPE	Jump on parity even	1	1	1	0	1	0	1	0	5-13
JPO	Jump on parity odd	1	1	1	0	0	0	1	0	5-13
PCHL	H & L to program counter	1	1	1	0	1	0	0	1	5-15
CALL										
CALL	Call unconditional	1	1	0	0	1	1	0	1	5-13
CC	Call on carry	1	1	0	1	1	1	0	0	5-14
CNC	Call on no carry	1	1	0	1	0	1	0	0	5-14
CZ	Call on zero	1	1	0	0	1	1	0	0	5-14
CNZ	Call on no zero	1	1	0	0	0	1	0	0	5-14
CP	Call on positive	1	1	1	1	0	1	0	0	5-14
CM	Call on minus	1	1	1	1	1	1	0	0	5-14
CPE	Call on parity even	1	1	1	0	1	1	0	0	5-14
CPO	Call on parity odd	1	1	1	0	0	1	0	0	5-14
RETURN										
RET	Return	1	1	0	0	1	0	0	1	5-14
RC	Return on carry	1	1	0	1	1	0	0	0	5-14
RNC	Return on no carry	1	1	0	1	0	0	0	0	5-14
RZ	Return on zero	1	1	0	0	1	0	0	0	5-14
RNZ	Return on no zero	1	1	0	0	0	0	0	0	5-14
RP	Return on positive	1	1	1	1	0	0	0	0	5-14
RM	Return on minus	1	1	1	1	1	0	0	0	5-14
RPE	Return on parity even	1	1	1	0	1	0	0	0	5-14
RPO	Return on parity odd	1	1	1	0	0	0	0	0	5-14
RESTART										
RST	Restart	1	1	A	A	A	1	1	1	5-14
INPUT/OUTPUT										
IN	Input	1	1	0	1	1	0	1	1	5-16
OUT	Output	1	1	0	1	0	0	1	1	5-16
INCREMENT AND DECREMENT										
INR r	Increment register	0	0	D	D	D	1	0	0	5-8
DCR r	Decrement register	0	0	D	D	D	1	0	1	5-8
INR M	Increment memory	0	0	1	1	0	1	0	0	5-8
DCR M	Decrement memory	0	0	1	1	0	1	0	1	5-8
INX B	Increment B & C registers	0	0	0	0	0	0	1	1	5-9
INX D	Increment D & E registers	0	0	0	1	0	0	1	1	5-9
INX H	Increment H & L registers	0	0	1	0	0	0	1	1	5-9
DCX B	Decrement B & C	0	0	0	0	1	0	1	1	5-9
DCX D	Decrement D & E	0	0	0	1	1	0	1	1	5-9
DCX H	Decrement H & L	0	0	1	0	1	0	1	1	5-9
ADD										
ADD r	Add register to A	1	0	0	0	0	S	S	S	5-6
ADC r	Add register to A with carry	1	0	0	0	1	S	S	S	5-6
ADD M	Add memory to A	1	0	C	0	0	1	1	0	5-6
ADC M	Add memory to A with carry	1	0	0	0	1	1	1	0	5-7
ADI	Add immediate to A	1	1	0	0	0	1	1	0	5-6
ACI	Add immediate to A with carry	1	1	0	0	1	1	1	0	5-7
DAD B	Add B & C to H & L	0	0	0	0	1	0	0	1	5-9
DAD D	Add D & E to H & L	0	0	0	1	1	0	0	1	5-9
DAD H	Add H & L to H & L	0	0	1	0	1	0	0	1	5-9
DAD SP	Add stack pointer to H & L	0	0	1	1	1	0	0	1	5-9
SUBTRACT										
SUB r	Subtract register from A	1	0	0	1	0	S	S	S	5-7
SBB r	Subtract register from A with borrow	1	0	0	1	1	S	S	S	5-7
SUB M	Subtract memory from A	1	0	0	1	0	1	1	0	5-7
SBB M	Subtract memory from A with borrow	1	0	0	1	1	1	1	0	5-8
SUI	Subtract immediate from A	1	1	0	1	0	1	1	0	5-7

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8085A INSTRUCTION SET SUMMARY (Cont'd)

Table 5-3

Mnemonic	Description	Instruction Code (1) D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	Page
SBI	Subtract immediate from A with borrow	1	1	0	1	1	1	1	0	5-8
LOGICAL										
ANA r	And register with A	1	0	1	0	0	S	S	S	5-9
XRA r	Exclusive OR register with A	1	0	1	0	1	S	S	S	5-10
ORA r	OR register with A	1	0	1	1	0	S	S	S	5-10
CMP r	Compare register with A	1	0	1	1	1	S	S	S	5-11
ANA M	And memory with A	1	0	1	0	0	1	1	0	5-10
XRA M	Exclusive OR memory with A	1	0	1	0	1	1	1	0	5-10
ORA M	OR memory with A	1	0	1	1	0	1	1	0	5-11
CMP M	Compare memory with A	1	0	1	1	1	1	1	0	5-11
ANI	And immediate with A	1	1	1	0	0	1	1	0	5-10
XRI	Exclusive OR immediate with A	1	1	1	0	1	1	1	0	5-10
ORI	OR immediate with A	1	1	1	1	0	1	1	0	5-11
CPI	Compare immediate with A	1	1	1	1	1	1	1	0	5-11
ROTATE										
RLC	Rotate A left	0	0	0	0	0	1	1	1	5-11
RRC	Rotate A right	0	0	0	0	1	1	1	1	5-12
RAL	Rotate A left through carry	0	0	0	1	0	1	1	1	5-12
RAR	Rotate A right through carry	0	0	0	1	1	1	1	1	5-12
SPECIALS										
CMA	Complement A	0	0	1	0	1	1	1	1	5-12
STC	Set carry	0	0	1	1	0	1	1	1	5-12
CMC	Complement carry	0	0	1	1	1	1	1	1	5-12
DAA	Decimal adjust A	0	0	1	0	0	1	1	1	5-9
CONTROL										
EI	Enable Interrupts	1	1	1	1	1	0	1	1	5-17
DI	Disable Interrupt	1	1	1	1	0	0	1	1	5-17
NOP	No-operation	0	0	0	0	0	0	0	0	5-17
HLT	Halt	0	1	1	1	0	1	1	0	5-17
NEW 8085A INSTRUCTIONS										
RIM	Read Interrupt Mask	0	0	1	0	0	0	0	0	5-17
SIM	Set Interrupt Mask	0	0	1	1	0	0	0	0	5-18

NOTES: 1. DDS or SSS: B 000, C 001, D 010, E011, H 100, L 101, Memory 110, A 111.

2. Two possible cycle times. (6/12) indicate instruction cycles dependent on condition flags.

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Chapter 6

MCS-85™

MCS-80™

Systems

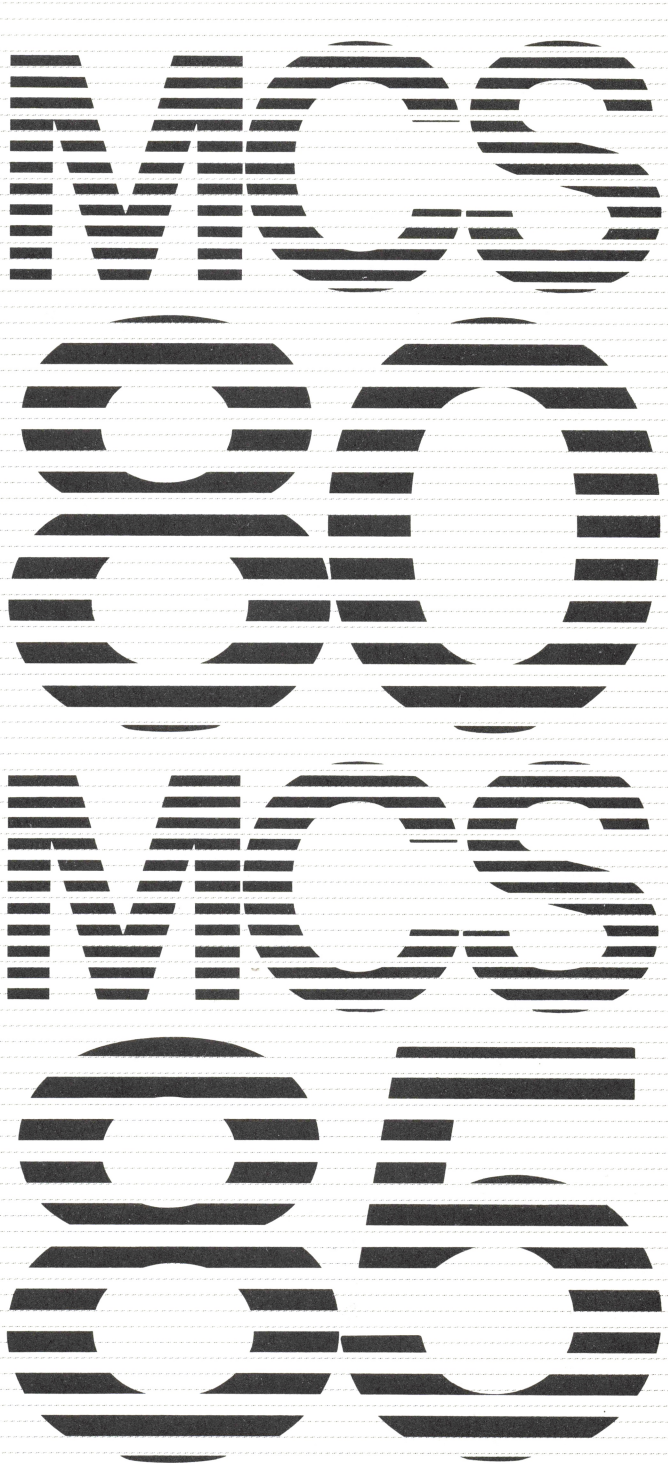
Support

Components

Peripherals

Static RAMs

ROMs-EPROMs



8085A/8085A-2
SINGLE CHIP 8-BIT N-CHANNEL MICROPROCESSORS

- **Single +5V Power Supply**
- **100% Software Compatible with 8080A**
- **1.3 μs Instruction Cycle (8085A); 0.8 μs (8085A-2)**
- **On-Chip Clock Generator (with External Crystal, LC or RC Network)**
- **On-Chip System Controller; Advanced Cycle Status Information Available for Large System Control**
- **Four Vectored Interrupt Inputs (One is non-Maskable) Plus an 8080A-compatible interrupt**
- **Serial In/Serial Out Port**
- **Decimal, Binary and Double Precision Arithmetic**
- **Direct Addressing Capability to 64k Bytes of Memory**

The Intel® 8085A is a complete 8 bit parallel Central Processing Unit (CPU). Its instruction set is 100% software compatible with the 8080A microprocessor, and it is designed to improve the present 8080A's performance by higher system speed. Its high level of system integration allows a minimum system of three IC's [8085A (CPU), 8156 (RAM/IO) and 8355/8755A (ROM/PROM/IO)] while maintaining total system expandability. The 8085A-2 is a faster version of the 8085A.

The 8085A incorporates all of the features that the 8224 (clock generator) and 8228 (system controller) provided for the 8080A, thereby offering a high level of system integration.

The 8085A uses a multiplexed data bus. The address is split between the 8 bit address bus and the 8 bit data bus. The on-chip address latches of 8155/8156/8355/8755A memory products allow a direct interface with the 8085A.

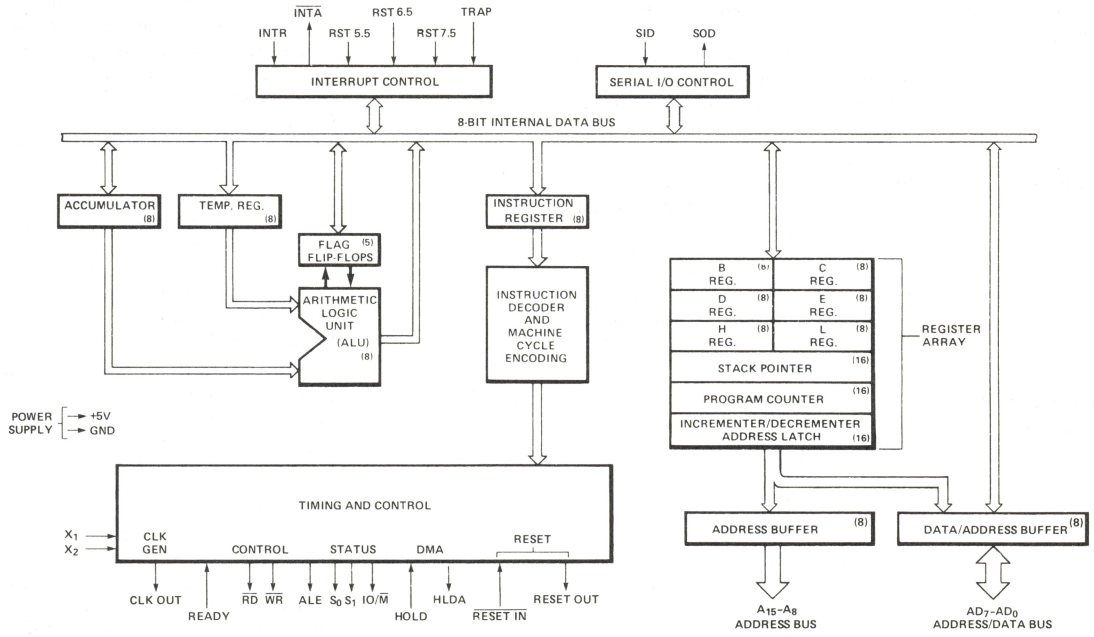


Figure 1. 8085A CPU Functional Block Diagram

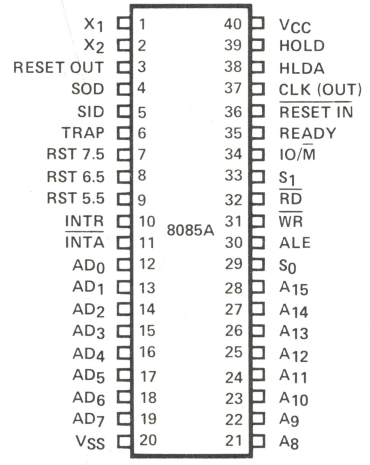


Figure 2. 8085A Pinout Diagram

8085A FUNCTIONAL PIN DEFINITION

The following describes the function of each pin:

Symbol — **Function**

A_8–A_{15} (Output, 3-state)
Address Bus: The most significant 8 bits of the memory address or the 8 bits of the I/O address, 3-stated during Hold and Halt modes and during RESET.

AD_{0-7} (Input/Output, 3-state)
Multiplexed Address/Data Bus: Lower 8 bits of the memory address (or I/O address) appear on the bus during the first clock cycle (T state) of a machine cycle. It then becomes the data bus during the second and third clock cycles.

ALE (Output)
Address Latch Enable: It occurs during the first clock state of a machine cycle and enables the address to get latched into the on-chip latch of peripherals. The falling edge of ALE is set to guarantee setup and hold times for the address information. The falling edge of ALE can also be used to strobe the status information. ALE is never 3-stated.

S_0, S_1, and IO/$\overline{M}$ (Output)
Machine cycle status:

IO/$\overline{M}$	S_1	S_0	Status
0	0	1	Memory write
0	1	0	Memory read
1	0	1	I/O write
1	1	0	I/O read
0	1	1	Opcode fetch
1	1	1	Interrupt Acknowledge
*	0	0	Halt
*	X	X	Hold
*	X	X	Reset

* = 3-state (high impedance)
X = unspecified

Symbol — **Function**

S_1 can be used as an advanced R/$\overline{W}$ status. IO/$\overline{M}$,S_0 and S_1 become valid at the beginning of a machine cycle and remain stable throughout the cycle. The falling edge of ALE may be used to latch the state of these lines.

$\overline{RD}$ (Output, 3-state)
READ control: A low level on $\overline{RD}$ indicates the selected memory or I/O device is to be read and that the Data Bus is available for the data transfer, 3-stated during Hold and Halt modes and during RESET.

$\overline{WR}$ (Output, 3-state)
WRITE control: A low level on $\overline{WR}$ indicates the data on the Data Bus is to be written into the selected memory or I/O location. Data is set up at the trailing edge of $\overline{WR}$. 3-stated during Hold and Halt modes and during RESET.

READY (Input)
If READY is high during a read or write cycle, it indicates that the memory or peripheral is ready to send or receive data. If READY is low, the cpu will wait an integral number of clock cycles for READY to go high before completing the read or write cycle.

HOLD (Input)
HOLD indicates that another master is requesting the use of the address and data buses. The cpu, upon receiving the hold request, will relinquish the use of the bus as soon as the completion of the current bus transfer. Internal processing can continue. The processor can regain the bus only after the HOLD is removed. When the HOLD is acknowledged, the Address, Data, $\overline{RD}$, $\overline{WR}$, and IO/$\overline{M}$ lines are 3-stated.

HLDA (Output)
HOLD ACKNOWLEDGE: Indicates that the cpu has received the HOLD request and that it will relinquish the bus in the next clock cycle. HLDA goes low after the Hold request is removed. The cpu takes the bus one half clock cycle after HLDA goes low.

INTR (Input)
INTERRUPT REQUEST: is used as a general purpose interrupt. It is sampled only during the next to the last clock cycle of an instruction and during Hold and Halt states. If it is active, the Program Counter (PC) will be inhibited from incrementing and an $\overline{INTA}$ will be issued. During this cycle a RESTART or CALL instruction can be inserted to jump to the interrupt service routine. The INTR is enabled and disabled by software. It is disabled by Reset and immediately after an interrupt is accepted.

8085A FUNCTIONAL PIN DESCRIPTION (Continued)

Symbol	Function
$\overline{INTA}$ (Output)	INTERRUPT ACKNOWLEDGE: Is used instead of (and has the same timing as) $\overline{RD}$ during the Instruction cycle after an INTR is accepted. It can be used to activate the 8259 Interrupt chip or some other interrupt port.
RST 5.5 RST 6.5 RST 7.5 (Inputs)	RESTART INTERRUPTS: These three inputs have the same timing as INTR except they cause an internal RESTART to be automatically inserted. The priority of these interrupts is ordered as shown in Table 1. These interrupts have a higher priority than INTR. In addition, they may be individually masked out using the SIM instruction.
TRAP (Input)	Trap interrupt is a nonmaskable RESTART interrupt. It is recognized at the same time as INTR or RST 5.5-7.5. It is unaffected by any mask or Interrupt Enable. It has the highest priority of any interrupt. (See Table 1.)
$\overline{RESET\ IN}$ (Input)	Sets the Program Counter to zero and resets the Interrupt Enable and HLDA flip-flops. The data and address buses and the control lines are 3-stated during RESET and because of the asynchronous nature of RESET, the processor's internal registers and flags may be altered by RESET with unpredictable results. $\overline{RESET\ IN}$ is a Schmitt-triggered input, allowing connection to an R-C network for power-on RESET delay. The cpu is held in the reset condition as long as $\overline{RESET\ IN}$ is applied.
RESET OUT (Output)	Indicates cpu is being reset. Can be used as a system reset. The signal is synchronized to the processor clock and lasts an integral number of clock periods.
X_1, X_2 (Input)	X_1 and X_2 are connected to a crystal, LC, or RC network to drive the internal clock generator. X_1 can also be an external clock input from a logic gate. The input frequency is divided by 2 to give the processor's internal operating frequency.
CLK (Output)	Clock Output for use as a system clock. The period of CLK is twice the X_1, X_2 input period.
SID (Input)	Serial input data line. The data on this line is loaded into accumulator bit 7 whenever a RIM instruction is executed.
SOD (Output)	Serial output data line. The output SOD is set or reset as specified by the SIM instruction.
V_{CC}	+5 volt supply.
V_{SS}	Ground Reference.

TABLE 1. INTERRUPT PRIORITY, RESTART ADDRESS, AND SENSITIVITY

Name	Priority	Address Branched To (1) When Interrupt Occurs	Type Trigger
TRAP	1	24H	Rising edge AND high level until sampled.
RST 7.5	2	3CH	Rising edge (latched).
RST 6.5	3	34H	High level until sampled.
RST 5.5	4	2CH	High level until sampled.
INTR	5	See Note (2).	High level until sampled.

NOTES:

(1) The processor pushes the PC on the stack before branching to the indicated address.
(2) The address branched to depends on the instruction provided to the cpu when the interrupt is acknowledged.

FUNCTIONAL DESCRIPTION

The 8085A is a complete 8-bit parallel central processor. It is designed with N-channel depletion loads and requires a single +5 volt supply. Its basic clock speed is 3 MHz (8085A) or 5 MHz (8085A-2), thus improving on the present 8080A's performance with higher system speed. Also it is designed to fit into a minimum system of three IC's: The cpu (8085A), a RAM/IO (8156), and a ROM or EPROM/IO chip (8355 or 8755A).

The 8085A has twelve addressable 8-bit registers. Four of them can function only as two 16-bit register pairs. Six others can be used interchangeably as 8-bit registers or as 16-bit register pairs. The 8085A register set is as follows:

Mnemonic	Register	Contents
ACC or A	Accumulator	8 bits
PC	Program Counter	16-bit address
BC,DE,HL	General-Purpose Registers; data pointer (HL)	8 bits x 6 or 16 bits x 3
SP	Stack Pointer	16-bit address
Flags or F	Flag Register	5 flags (8-bit space)

The 8085A uses a multiplexed Data Bus. The address is split between the higher 8-bit Address Bus and the lower 8-bit Address/Data Bus. During the first T state (clock cycle) of a machine cycle the low order address is sent out on the Address/Data bus. These lower 8 bits may be latched externally by the Address Latch Enable signal (ALE). During the rest of the machine cycle the data bus is used for memory or I/O data.

The 8085A provides $\overline{RD}$, $\overline{WR}$, S_0, S_1, and IO/$\overline{M}$ signals for bus control. An Interrupt Acknowledge signal ($\overline{INTA}$) is also provided. HOLD and all Interrupts are synchronized with the processor's internal clock. The 8085A also provides Serial Input Data (SID) and Serial Output Data (SOD) lines for simple serial interface.

In addition to these features, the 8085A has three maskable, vector interrupt pins and one nonmaskable TRAP interrupt.

INTERRUPT AND SERIAL I/O

The 8085A has 5 interrupt inputs: INTR, RST 5.5, RST 6.5, RST 7.5, and TRAP. INTR is identical in function to the 8080A INT. Each of the three RESTART inputs, 5.5, 6.5, and 7.5, has a programmable mask. TRAP is also a RESTART interrupt but it is nonmaskable.

The three maskable interrupts cause the internal execution of RESTART (saving the program counter in the stack and branching to the RESTART address) if the interrupts are enabled and if the interrupt mask is not set. The nonmaskable TRAP causes the internal execution of a RESTART vector independent of the state of the interrupt enable or masks. (See Table 1.)

There are two different types of inputs in the restart interrupts. RST 5.5 and RST 6.5 are *high level-sensitive* like INTR (and INT on the 8080) and are recognized with the same timing as INTR. RST 7.5 is *rising edge-sensitive.*

For RST 7.5, only a pulse is required to set an internal flip-flop which generates the internal interrupt request. (See Section 5.2.7.) The RST 7.5 request flip-flop remains set until the request is serviced. Then it is reset automatically. This flip-flop may also be reset by using the SIM instruction or by issuing a $\overline{RESET\ IN}$ to the 8085A. The RST 7.5 internal flip-flop will be set by a pulse on the RST 7.5 pin even when the RST 7.5 interrupt is masked out.

The status of the three RST interrupt masks can only be affected by the SIM instruction and $\overline{RESET\ IN}$. (See SIM, Chapter 5.

The interrupts are arranged in a fixed priority that determines which interrupt is to be recognized if more than one is pending as follows: TRAP — highest priority, RST 7.5, RST 6.5, RST 5.5, INTR — lowest priority. This priority scheme does not take into account the priority of a routine that was started by a higher priority interrupt. RST 5.5 can interrupt an RST 7.5 routine if the interrupts are re-enabled before the end of the RST 7.5 routine.

The TRAP interrupt is useful for catastrophic events such as power failure or bus error. The TRAP input is recognized just as any other interrupt but has the highest priority. It is not affected by any flag or mask. The TRAP input is both *edge and level sensitive.* The TRAP input must go high and remain high until it is acknowledged. It will not be recognized again until it goes low, then high again. This avoids any false triggering due to noise or logic glitches. Figure 3 illustrates the TRAP interrupt request circuitry within the 8085A. Note that the servicing of any interrupt (TRAP, RST 7.5, RST 6.5, RST 5.5, INTR) disables all future interrupts (except TRAPs) until an EI instruction is executed.

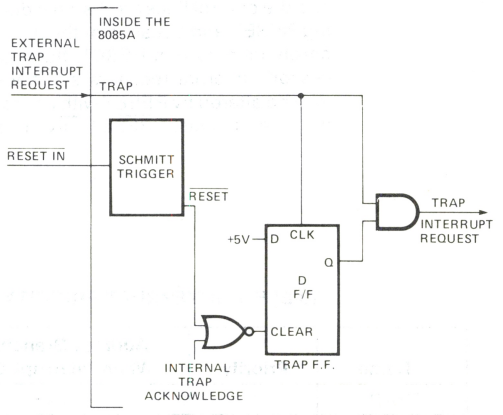


Figure 3. TRAP and $\overline{RESET\ IN}$ Circuit

The TRAP interrupt is special in that it disables interrupts, but preserves the previous interrupt enable status. Performing the first RIM instruction following a TRAP interrupt allows you to determine whether interrupts were enabled or disabled prior to the TRAP. All subsequent RIM instructions provide current interrupt enable status. Performing a RIM instruction following INTR, or RST 5.5–7.5 will provide current Interrupt Enable status, revealing that Interrupts are disabled. See the description of the RIM instruction in Chapter 5.

The serial I/O system is also controlled by the RIM and SIM instructions. SID is read by RIM, and SIM sets the SOD data.

DRIVING THE X_1 AND X_2 INPUTS

You may drive the clock inputs of the 8085A or 8085A-2 with a crystal, an LC tuned circuit, an RC network, or an external clock source. The driving frequency must be at least 1 MHz, and must be twice the desired internal clock frequency; hence, the 8085A is operated with a 6 MHz crystal (for 3 MHz clock), and the 8085A-2 can be operated with a 10 MHz crystal (for 5 MHz clock). If a crystal is used, it must have the following characteristics:

Parallel resonance at twice the clock frequency desired
C_L (load capacitance) $\leq$ 30 pf
C_S (shunt capacitance) $\leq$ 7 pf
R_S (equivalent shunt resistance) $\leq$ 75 Ohms
Drive level: 10 mW
Frequency tolerance: $\pm$.005% (suggested)

Note the use of the 20pF capacitor between X_2 and ground. This capacitor is required with crystal frequencies below 4 MHz to assure oscillator startup at the correct frequency. A parallel-resonant LC circuit may be used as the frequency-determining network for the 8085A, providing that its frequency tolerance of approximately $\pm$10% is acceptable. The components are chosen from the formula:

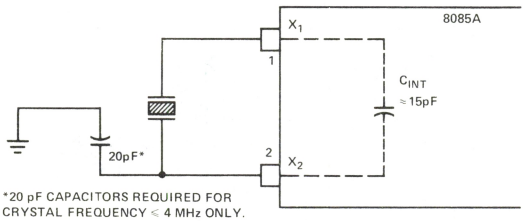
$$f = \frac{1}{2\pi\sqrt{L(C_{ext} + C_{int})}}$$

To minimize variations in frequency, it is recommended that you choose a value for C_{ext} that is at least twice that of C_{int}, or 30 pF. The use of an LC circuit is not recommended for frequencies higher than approximately 5 MHz.

An RC circuit may be used as the frequency-determining network for the 8085A if maintaining a precise clock frequency is of no importance. Variations in the on-chip timing generation can cause a wide variation in frequency when using the RC mode. Its advantage is its low component cost. The driving frequency generated by the circuit shown is approximately 3 MHz. It is not recommended that frequencies greatly higher or lower than this be attempted.

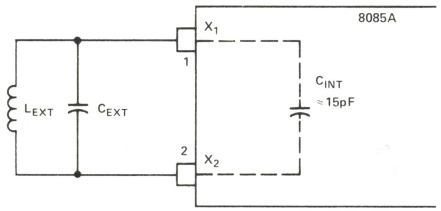
Figure 4 shows the recommended clock driver circuits. Note in D and E that pullup resistors are required to assure that the high level voltage of the input is at least 4 V.

For driving frequencies up to and including 6 MHz you may supply the driving signal to X_1 and leave X_2 open-circuited (Figue 4D). If the driving frequency is from 6 MHz to 10 MHz, stability of the clock generator will be improved by driving both X_1 and X_2 with a push-pull source (Figure 4E). To prevent self-oscillation of the 8085A, be sure that X_2 is not coupled back to X_1 through the driving circuit.

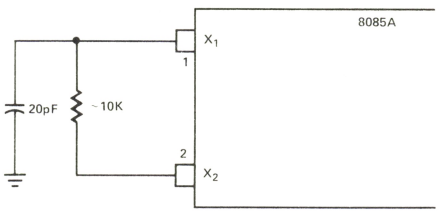


*20 pF CAPACITORS REQUIRED FOR CRYSTAL FREQUENCY ≤ 4 MHz ONLY.

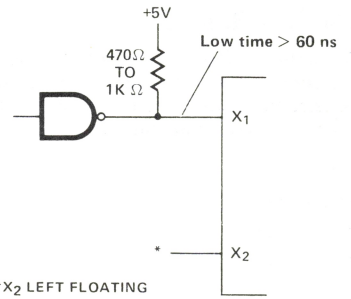
A. Quartz Crystal Clock Driver



B. LC Tuned Circuit Clock Driver

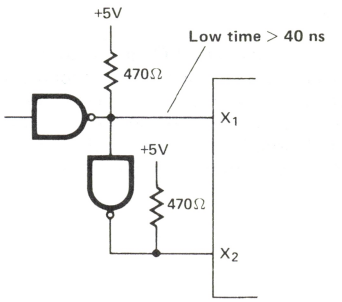


C. RC Circuit Clock Driver



*X_2 LEFT FLOATING

D. 1-6 MHz Input Frequency External Clock Driver Circuit



E. 1-10 MHz Input Frequency External Clock Driver Circuit

Figure 4. Clock Driver Circuits

GENERATING AN 8085A WAIT STATE

If your system requirements are such that slow memories or peripheral devices are being used, the circuit shown in Figure 5 may be used to insert one WAIT state in each 8085A machine cycle

The D flip-flops should be chosen so that

- CLK is rising edge-triggered
- CLEAR is low-level active.

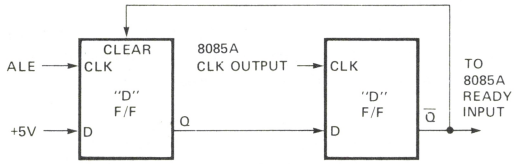


Figure 5. Generation of a Wait State for 8085A CPU

As in the 8080, the READY line is used to extend the read and write pulse lengths so that the 8085A can be used with slow memory. HOLD causes the cpu to relinquish the bus when it is through with it by floating the Address and Data Buses.

SYSTEM INTERFACE

The 8085A family includes memory components, which are directly compatible to the 8085A cpu. For example, a system consisting of the three chips, 8085A, 8156, and 8355 will have the following features:

- 2K Bytes ROM
- 256 Bytes RAM
- 1 Timer/Counter
- 4 8-bit I/O Ports
- 1 6-bit I/O Port
- 4 Interrupt Levels
- Serial In/Serial Out Ports

This minimum system, using the standard I/O technique is as shown in Figure 6.

In addition to standard I/O, the memory mapped I/O offers an efficient I/O addressing technique. With this technique, an area of memory address space is assigned for I/O address, thereby, using the memory address for I/O manipulation. Figure 7 shows the system configuration of Memory Mapped I/O using 8085A.

The 8085A cpu can also interface with the standard memory that does *not* have the multiplexed address/data bus. It will require a simple 8212 (8-bit latch) as shown in Figure 8.

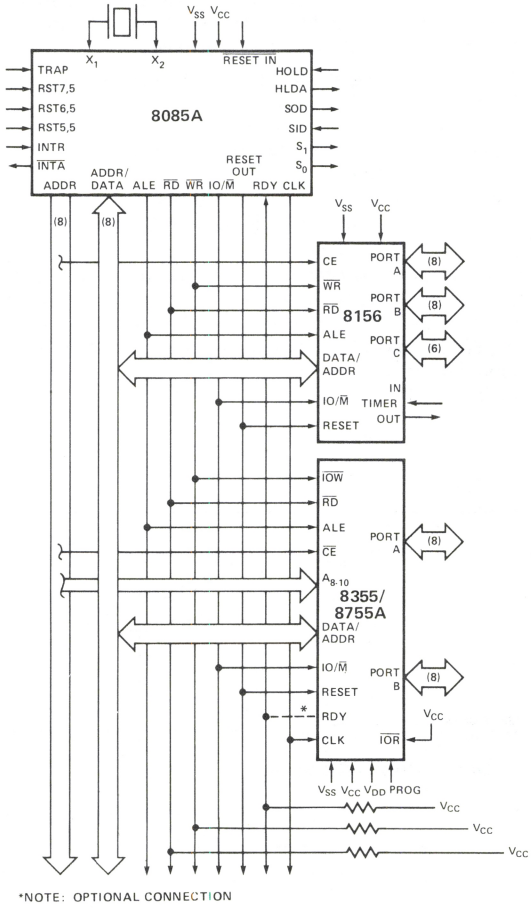


Figure 6. 8085A Minimum System (Standard I/O Technique)

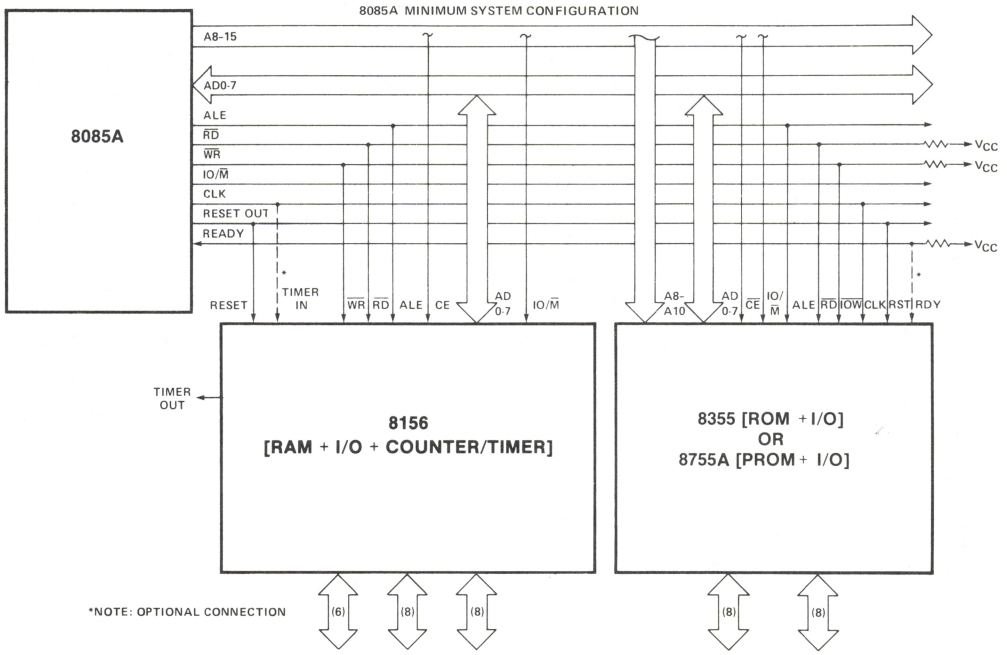


Figure 7. MCS-85™ Minimum System (Memory Mapped I/O)

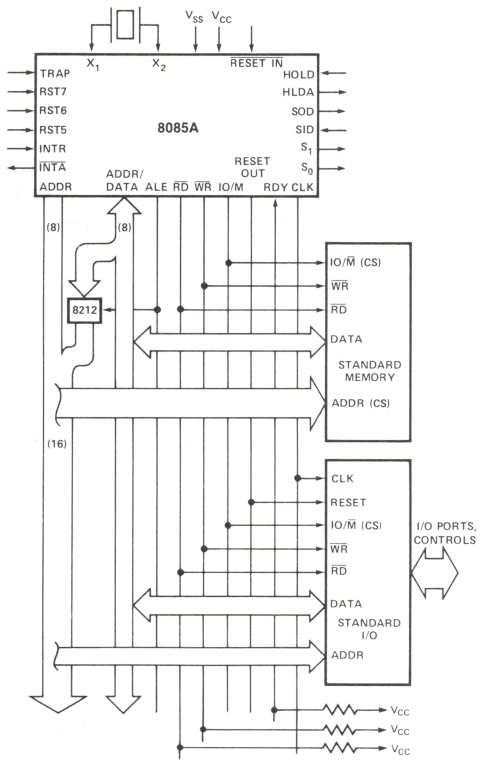


Figure 8. MCS-85™ System (Using Standard Memories)

BASIC SYSTEM TIMING

The 8085A has a multiplexed Data Bus. ALE is used as a strobe to sample the lower 8-bits of address on the Data Bus. Figure 9 shows an instruction fetch, memory read and I/O write cycle (as would occur during processing of the OUT instruction). Note that during the I/O write and read cycle that the I/O port address is copied on both the upper and lower half of the address.

There are seven possible types of machine cycles. Which of these seven takes place is defined by the status of the three status lines ($IO/\overline{M}$, S_1, S_0) and the three control signals ($\overline{RD}$, $\overline{WR}$, and $\overline{INTA}$). (See Table 2.) The status lines can be used as advanced controls (for device selection, for example), since they become active at the T_1 state, at the outset of each machine cycle. Control lines $\overline{RD}$ and $\overline{WR}$ become active later, at the time when the transfer of data is to take place, so are used as command lines.

A machine cycle normally consists of three T states, with the exception of OPCODE FETCH, which normally has either four or six T states (unless WAIT or HOLD states are forced by the receipt of $\overline{READY}$ or HOLD inputs). Any T state must be one of ten possible states, shown in Table 3.

TABLE 2. 8085A MACHINE CYCLE CHART

MACHINE CYCLE		STATUS			CONTROL		
		$IO/\overline{M}$	S1	S0	$\overline{RD}$	$\overline{WR}$	$\overline{INTA}$
OPCODE FETCH	(OF)	0	1	1	0	1	1
MEMORY READ	(MR)	0	1	0	0	1	1
MEMORY WRITE	(MW)	0	0	1	1	0	1
I/O READ	(IOR)	1	1	0	0	1	1
I/O WRITE	(IOW)	1	0	1	1	0	1
ACKNOWLEDGE OF INTR	(INA)	1	1	1	1	1	0
BUS IDLE	(BI): DAD	0	1	0	1	1	1
	ACK. OF RST,TRAP	1	1	1	1	1	1
	HALT	TS	0	0	TS	TS	1

TABLE 3. 8085A MACHINE STATE CHART

Machine State	Status & Buses				Control		
	S1,S0	$IO/\overline{M}$	A_8-A_{15}	AD_0-AD_7	$\overline{RD},\overline{WR}$	$\overline{INTA}$	ALE
T_1	X	X	X	X	1	1	1*
T_2	X	X	X	X	X	X	0
T_{WAIT}	X	X	X	X	X	X	0
T_3	X	X	X	X	X	X	0
T_4	1	0†	X	TS	1	1	0
T_5	1	0†	X	TS	1	1	0
T_6	1	0†	X	TS	1	1	0
T_{RESET}	X	TS	TS	TS	TS	1	0
T_{HALT}	0	TS	TS	TS	TS	1	0
T_{HOLD}	X	TS	TS	TS	TS	1	0

0 = Logic "0" TS = High Impedance
1 = Logic "1" X = Unspecified

* ALE not generated during 2nd and 3rd machine cycles of DAD instruction.
† IO/M = 1 during T_4-T_6 of INA machine cycle.

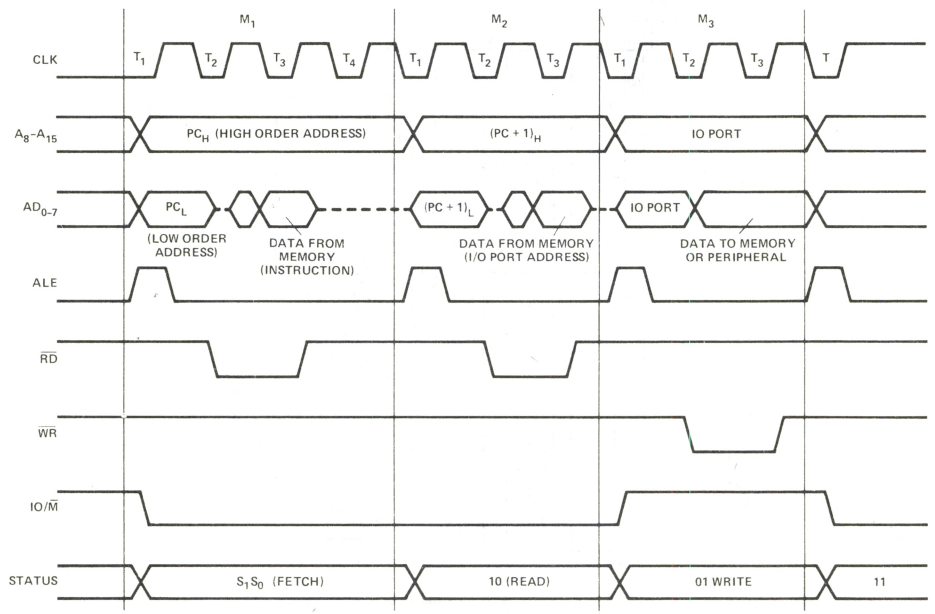


Figure 9. 8085A Basic System Timing

TABLE 4. ABSOLUTE MAXIMUM RATINGS*

Ambient Temperature Under Bias. . . . . 0°C to 70°C
Storage Temperature . . . . . -65°C to +150°C
Voltage on Any Pin
With Respect to Ground . . . . . -0.5V to +7V
Power Dissipation . . . . . 1.5 Watt

*COMMENT

Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

TABLE 5. D.C. CHARACTERISTICS

(T_A = 0°C to 70°C; V_{CC} = 5V ±5%; V_{SS} = 0V; unless otherwise specified)

Symbol	Parameter	Min.	Max.	Units	Test Conditions
V_{IL}	Input Low Voltage	-0.5	+0.8	V	
V_{IH}	Input High Voltage	2.0	V_{CC}+0.5	V	
V_{OL}	Output Low Voltage		0.45	V	I_{OL} = 2mA
V_{OH}	Output High Voltage	2.4		V	I_{OH} = -400μA
I_{CC}	Power Supply Current		170	mA	
I_{IL}	Input Leakage		±10	μA	$V_{in} = V_{CC}$
I_{LO}	Output Leakage		±10	μA	$0.45V \leqslant V_{out} \leqslant V_{CC}$
V_{ILR}	Input Low Level, RESET	-0.5	+0.8	V	
V_{IHR}	Input High Level, RESET	2.4	V_{CC} +0.5	V	
V_{HY}	Hysteresis, RESET	0.25		V	

TABLE 6. A.C. CHARACTERISTICS

$T_A = 0°C$ to $70°C$; $V_{CC} = 5V \pm 5\%$; $V_{SS} = 0V$

Symbol	Parameter	8085A[2]		8085A-2[2] (Preliminary)		Units
		Min.	Max.	Min.	Max.	
t_{CYC}	CLK Cycle Period	320	2000	200	2000	ns
t_1	CLK Low Time (Standard CLK Loading)	80		40		ns
t_2	CLK High Time (Standard CLK Loading)	120		70		ns
t_r, t_f	CLK Rise and Fall Time		30		30	ns
t_{XKR}	X_1 Rising to CLK Rising	30	120	30	100	ns
t_{XKF}	X_1 Rising to CLK Falling	30	150	30	110	ns
t_{AC}	A_{8-15} Valid to Leading Edge of Control[1]	270		115		ns
t_{ACL}	A_{0-7} Valid to Leading Edge of Control	240		115		ns
t_{AD}	A_{0-15} Valid to Valid Data In		575		350	ns
t_{AFR}	Address Float After Leading Edge of $\overline{READ}$ ($\overline{INTA}$)		0		0	ns
t_{AL}	A_{8-15} Valid Before Trailing Edge of ALE[1]	115		50		ns
t_{ALL}	A_{0-7} Valid Before Trailing Edge of ALE	90		50		ns
t_{ARY}	READY Valid from Address Valid		220		100	ns
t_{CA}	Address (A_{8-15}) Valid After Control	120		60		ns
t_{CC}	Width of Control Low ($\overline{RD}$, $\overline{WR}$, $\overline{INTA}$) Edge of ALE	400		230		ns
t_{CL}	Trailing Edge of Control to Leading Edge of ALE	50		25		ns
t_{DW}	Data Valid to Trailing Edge of $\overline{WRITE}$	420		230		ns
t_{HABE}	HLDA to Bus Enable		210		150	ns
t_{HABF}	Bus Float After HLDA		210		150	ns
t_{HACK}	HLDA Valid to Trailing Edge of CLK	110		40		ns
t_{HDH}	HOLD Hold Time	0		0		ns
t_{HDS}	HOLD Setup Time to Trailing Edge of CLK	170		120		ns
t_{INH}	INTR Hold Time	0		0		ns
t_{INS}	INTR, RST, and TRAP Setup Time to Falling Edge of CLK	160		150		ns
t_{LA}	Address Hold Time After ALE	100		50		ns
t_{LC}	Trailing Edge of ALE to Leading Edge of Control	130		60		ns
t_{LCK}	ALE Low During CLK High	100		50		ns
t_{LDR}	ALE to Valid Data During Read		460		270	ns
t_{LDW}	ALE to Valid Data During Write		200		120	ns
t_{LL}	ALE Width	140		80		ns
t_{LRY}	ALE to READY Stable		110		30	ns

Table 6. A.C. Characteristics (Cont.)

Symbol	Parameter	8085A[2]		8085A-2[2] (Preliminary)		Units
		Min.	Max.	Min.	Max.	
t_{RAE}	Trailing Edge of $\overline{READ}$ to Re-Enabling of Address	150		90		ns
t_{RD}	$\overline{READ}$ (or $\overline{INTA}$) to Valid Data		300		150	ns
t_{RV}	Control Trailing Edge to Leading Edge of Next Control	400		220		ns
t_{RDH}	Data Hold Time After $\overline{READ}$ $\overline{INTA}$[7]	0		0		ns
t_{RYH}	READY Hold Time	0		0		ns
t_{RYS}	READY Setup Time to Leading Edge of CLK	110		100		ns
t_{WD}	Data Valid After Trailing Edge of $\overline{WRITE}$	100		60		ns
t_{WDL}	LEADING Edge of WRITE to Data Valid		40		20	ns

Notes:
1. A_8-A_{15} address Specs apply to IO/$\overline{M}$, S_0, and S_1 except A_8-A_{15} are undefined during T_4-T_6 of OF cycle whereas IO/$\overline{M}$, S_0, and S_1 are stable.
2. Test conditions: t_{CYC} = 320 ns (8085A)/200 ns (8085A-2); C_L = 150 pF.
3. For all output timing where C_L = 150 pF use the following correction factors:
   25 pF ≤ C_L < 150 pF: −0.10 ns/pF
   150 pF < C_L ≤ 300 pF: +0.30 ns/pF
4. Output timings are measured with purely capacitive load.
5. All timings are measured at output votage V_L = 0.8V, V_H = 2.0V, and 1.5V with 20 ns rise and fall time on inputs.
6. To calculate timing specifications at other values of t_{CYC} use Table 7.
7. Data hold time is guaranteed under all loading conditions.

Input Waveform for A.C. Tests:

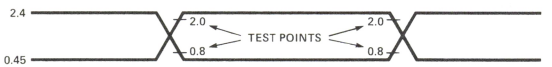


TABLE 7. BUS TIMING SPECIFICATION AS A T_{CYC} DEPENDENT

8085A

t_{AL}	–	(1/2) T - 45	MIN
t_{LA}	–	(1/2) T - 60	MIN
t_{LL}	–	(1/2) T - 20	MIN
t_{LCK}	–	(1/2) T - 60	MIN
t_{LC}	–	(1/2) T - 30	MIN
t_{AD}	–	(5/2 + N) T - 225	MAX
t_{RD}	–	(3/2 + N) T - 180	MAX
t_{RAE}	–	(1/2) T - 10	MIN
t_{CA}	–	(1/2) T - 40	MIN
t_{DW}	–	(3/2 + N) T – 60	MIN
t_{WD}	–	(1/2) T - 60	MIN
t_{CC}	–	(3/2 + N) T - 80	MIN
t_{CL}	–	(1/2) T - 110	MIN
t_{ARY}	–	(3/2) T - 260	MAX
t_{HACK}	–	(1/2) T - 50	MIN
t_{HABF}	–	(1/2) T + 50	MAX
t_{HABE}	–	(1/2) T + 50	MAX
t_{AC}	–	(2/2) T - 50	MIN
t_1	–	(1/2) T - 80	MIN
t_2	–	(1/2) T - 40	MIN
t_{RV}	–	(3/2) T - 80	MIN
t_{LDR}	–	(4/2) T - 180	MAX

NOTE: N is equal to the total WAIT states.
T = t_{CYC}.

8085A-2 (Preliminary)

t_{AL}	–	(1/2) T - 50	MIN
t_{LA}	–	(1/2) T - 50	MIN
t_{LL}	–	(1/2) T - 20	MIN
t_{LCK}	–	(1/2) T - 50	MIN
t_{LC}	–	(1/2) T - 40	MIN
t_{AD}	–	(5/2 + N) T - 150	MAX
t_{RD}	–	(3/2 + N) T - 150	MAX
t_{RAE}	–	(1/2) T - 10	MIN
t_{CA}	–	(1/2) T - 40	MIN
t_{DW}	–	(3/2 + N) T – 70	MIN
t_{WD}	–	(1/2) T - 40	MIN
t_{CC}	–	(3/2 + N) T - 70	MIN
t_{CL}	–	(1/2) T - 75	MIN
t_{ARY}	–	(3/2) T - 200	MAX
t_{HACK}	–	(1/2) T - 60	MIN
t_{HABF}	–	(1/2) T + 50	MAX
t_{HABE}	–	(1/2) T + 50	MAX
t_{AC}	–	(2/2) T - 85	MIN
t_1	–	(1/2) T - 60	MIN
t_2	–	(1/2) T - 30	MIN
t_{RV}	–	(3/2) T - 80	MIN
t_{LDR}	–	(4/2) T - 130	MAX

NOTE: N is equal to the total WAIT states.
T = t_{CYC}.

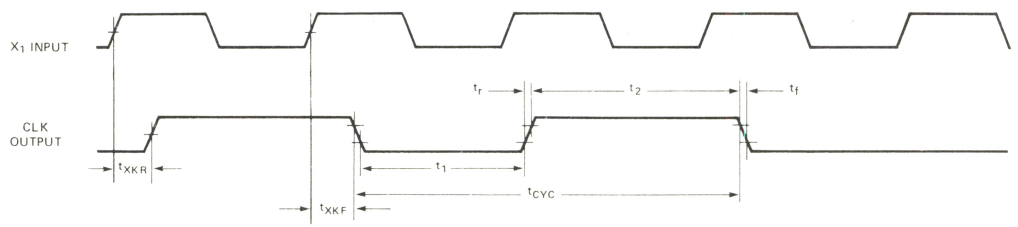
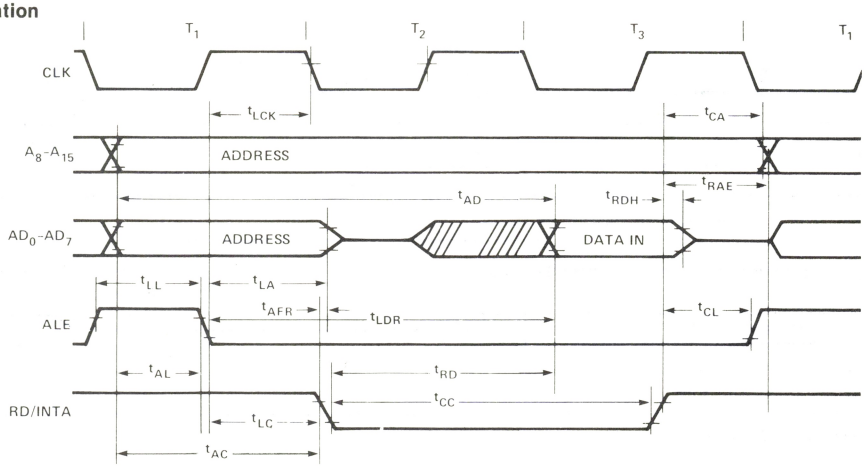
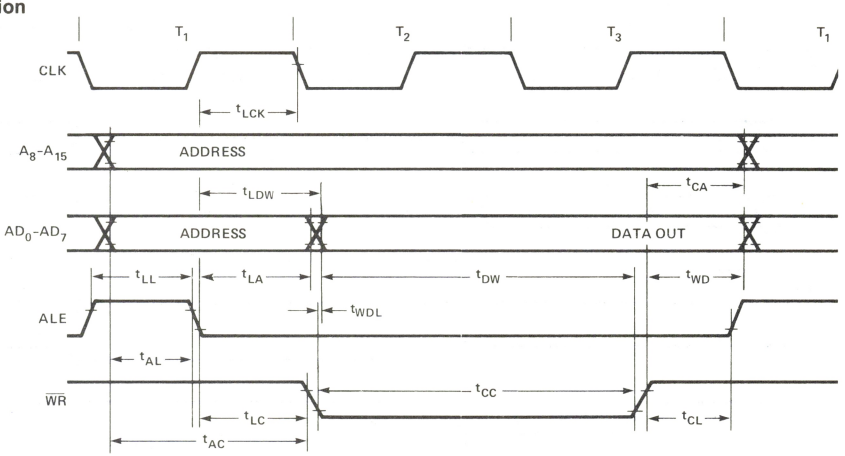


Figure 10. Clock Timing Waveform

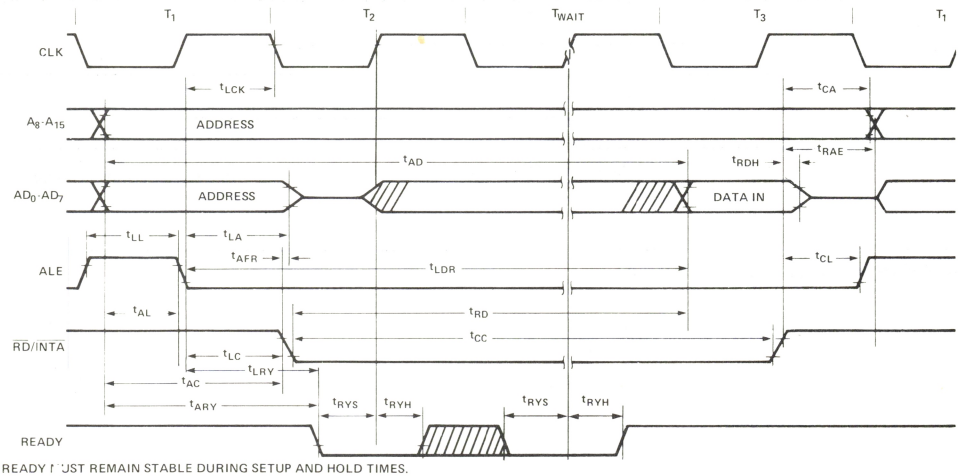
Read Operation



Write Operation



Read operation with Wait Cycle (Typical) — same READY timing applies to WRITE operation.



NOTE 1: READY MUST REMAIN STABLE DURING SETUP AND HOLD TIMES.

Figure 11. 8085A Bus Timing, With and Without Wait

Hold Operation

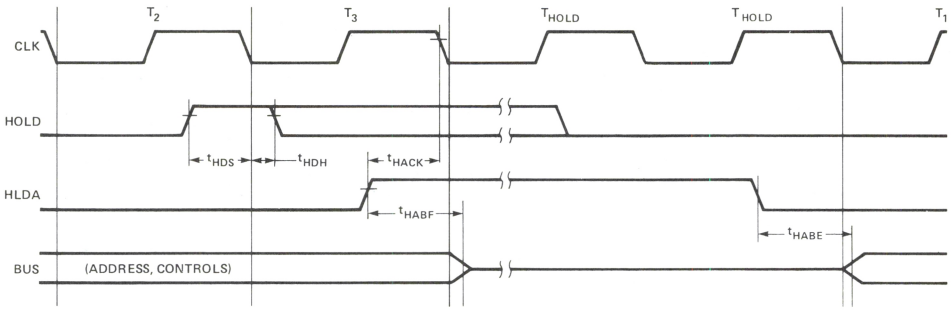


Figure 12. 8085A Hold Timing.

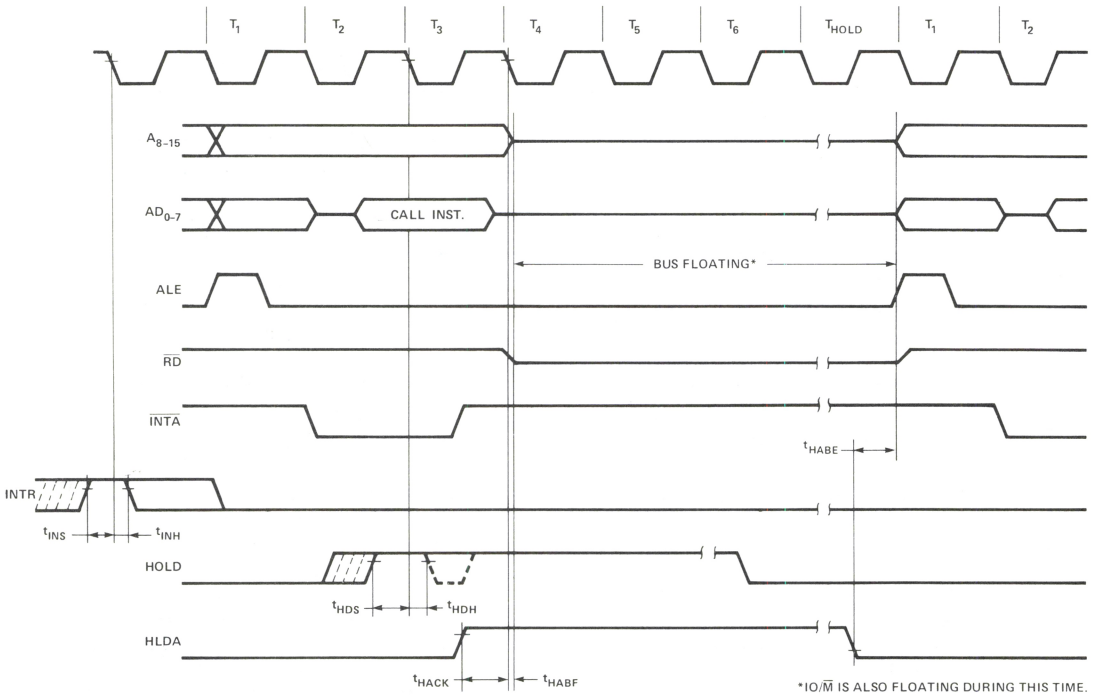


Figure 13. 8085A Interrupt and Hold Timing

8085A INSTRUCTION SET SUMMARY BY FUNCTIONAL GROUPING

Table 6-1

Mnemonic	Description	Instruction Code (1) D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	Page
MOVE, LOAD, AND STORE										
MOVr1 r2	Move register to register	0	1	D	D	D	S	S	S	5-4
MOV M,r	Move register to memory	0	1	1	1	0	S	S	S	5-4
MOV r,M	Move memory to register	0	1	D	D	D	1	1	0	5-4
MVI r	Move immediate register	0	0	D	D	D	1	1	0	5-4
MVI M	Move immediate memory	0	0	1	1	0	1	1	0	5-4
LXI B	Load immediate register Pair B & C	0	0	0	0	0	0	0	1	5-5
LXI D	Load immediate register Pair D & E	0	0	0	1	0	0	0	1	5-5
LXI H	Load immediate register Pair H & L	0	0	1	0	0	0	0	1	5-5
STAX B	Store A indirect	0	0	0	0	0	0	1	0	5-6
STAX D	Store A indirect	0	0	0	1	0	0	1	0	5-6
LDAX B	Load A indirect	0	0	0	0	1	0	1	0	5-5
LDAX D	Load A indirect	0	0	0	1	1	0	1	0	5-5
STA	Store A direct	0	0	1	1	0	0	1	0	5-5
LDA	Load A direct	0	0	1	1	1	0	1	0	5-5
SHLD	Store H & L direct	0	0	1	0	0	0	1	0	5-5
LHLD	Load H & L direct	0	0	1	0	1	0	1	0	5-5
XCHG	Exchange D & E, H & L Registers	1	1	1	0	1	0	1	1	5-6
STACK OPS										
PUSH B	Push register Pair B & C on stack	1	1	0	0	0	1	0	1	5-15
PUSH D	Push register Pair D & E on stack	1	1	0	1	0	1	0	1	5-15
PUSH H	Push register Pair H & L on stack	1	1	1	0	0	1	0	1	5-15
PUSH PSW	Push A and Flags on stack	1	1	1	1	0	1	0	1	5-15
POP B	Pop register Pair B & C off stack	1	1	0	0	0	0	0	1	5-15
POP D	Pop register Pair D & E off stack	1	1	0	1	0	0	0	1	5-15
POP H	Pop register Pair H & L off stack	1	1	1	0	0	0	0	1	5-15
POP PSW	Pop A and Flags off stack	1	1	1	1	0	0	0	1	5-15
XTHL	Exchange top of stack, H & L	1	1	1	0	0	0	1	1	5-16
SPHL	H & L to stack pointer	1	1	1	1	1	0	0	1	5-16
LXI SP	Load immediate stack pointer	0	0	1	1	0	0	0	1	5-5
INX SP	Increment stack pointer	0	0	1	1	0	0	1	1	5-9
DCX SP	Decrement stack pointer	0	0	1	1	1	0	1	1	5-9
JUMP										
JMP	Jump unconditional	1	1	0	0	0	0	1	1	5-13
JC	Jump on carry	1	1	0	1	1	0	1	0	5-13
JNC	Jump on no carry	1	1	0	1	0	0	1	0	5-13
JZ	Jump on zero	1	1	0	0	1	0	1	0	5-13
JNZ	Jump on no zero	1	1	0	0	0	0	1	0	5-13
JP	Jump on positive	1	1	1	1	0	0	1	0	5-13
JM	Jump on minus	1	1	1	1	1	0	1	0	5-13
JPE	Jump on parity even	1	1	1	0	1	0	1	0	5-13
JPO	Jump on parity odd	1	1	1	0	0	0	1	0	5-13
PCHL	H & L to program counter	1	1	1	0	1	0	0	1	5-15
CALL										
CALL	Call unconditional	1	1	0	0	1	1	0	1	5-13
CC	Call on carry	1	1	0	1	1	1	0	0	5-14
CNC	Call on no carry	1	1	0	1	0	1	0	0	5-14
CZ	Call on zero	1	1	0	0	1	1	0	0	5-14
CNZ	Call on no zero	1	1	0	0	0	1	0	0	5-14
CP	Call on positive	1	1	1	1	0	1	0	0	5-14
CM	Call on minus	1	1	1	1	1	1	0	0	5-14
CPE	Call on parity even	1	1	1	0	1	1	0	0	5-14
CPO	Call on parity odd	1	1	1	0	0	1	0	0	5-14
RETURN										
RET	Return	1	1	0	0	1	0	0	1	5-14
RC	Return on carry	1	1	0	1	1	0	0	0	5-14
RNC	Return on no carry	1	1	0	1	0	0	0	0	5-14
RZ	Return on zero	1	1	0	0	1	0	0	0	5-14
RNZ	Return on no zero	1	1	0	0	0	0	0	0	5-14
RP	Return on positive	1	1	1	1	0	0	0	0	5-14
RM	Return on minus	1	1	1	1	1	0	0	0	5-14
RPE	Return on parity even	1	1	1	0	1	0	0	0	5-14
RPO	Return on parity odd	1	1	1	0	0	0	0	0	5-14
RESTART										
RST	Restart	1	1	A	A	A	1	1	1	5-14
INPUT/OUTPUT										
IN	Input	1	1	0	1	1	0	1	1	5-16
OUT	Output	1	1	0	1	0	0	1	1	5-16
INCREMENT AND DECREMENT										
INR r	Increment register	0	0	D	D	D	1	0	0	5-8
DCR r	Decrement register	0	0	D	D	D	1	0	1	5-8
INR M	Increment memory	0	0	1	1	0	1	0	0	5-8
DCR M	Decrement memory	0	0	1	1	0	1	0	1	5-8
INX B	Increment B & C registers	0	0	0	0	0	0	1	1	5-9
INX D	Increment D & E registers	0	0	0	1	0	0	1	1	5-9
INX H	Increment H & L registers	0	0	1	0	0	0	1	1	5-9
DCX B	Decrement B & C	0	0	0	0	1	0	1	1	5-9
DCX D	Decrement D & E	0	0	0	1	1	0	1	1	5-9
DCX H	Decrement H & L	0	0	1	0	1	0	1	1	5-9
ADD										
ADD r	Add register to A	1	0	0	0	0	S	S	S	5-6
ADC r	Add register to A with carry	1	0	0	0	1	S	S	S	5-6
ADD M	Add memory to A	1	0	0	0	0	1	1	0	5-6
ADC M	Add memory to A with carry	1	0	0	0	1	1	1	0	5-7
ADI	Add immediate to A	1	1	0	0	0	1	1	0	5-6
ACI	Add immediate to A with carry	1	1	0	0	1	1	1	0	5-7
DAD B	Add B & C to H & L	0	0	0	0	1	0	0	1	5-9
DAD D	Add D & E to H & L	0	0	0	1	1	0	0	1	5-9
DAD H	Add H & L to H & L	0	0	1	0	1	0	0	1	5-9
DAD SP	Add stack pointer to H & L	0	0	1	1	1	0	0	1	5-9
SUBTRACT										
SUB r	Subtract register from A	1	0	0	1	0	S	S	S	5-7
SBB r	Subtract register from A with borrow	1	0	0	1	1	S	S	S	5-7
SUB M	Subtract memory from A	1	0	0	1	0	1	1	0	5-7
SBB M	Subtract memory from A with borrow	1	0	0	1	1	1	1	0	5-8
SUI	Subtract immediate from A	1	1	0	1	0	1	1	0	5-7

*All mnemonics copyrighted © Intel Corporation 1976.

8085A INSTRUCTION SET SUMMARY (Cont'd)

Table 6-1

Mnemonic	Description	Instruction Code (1) D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	Page
SBI	Subtract immediate from A with borrow	1	1	0	1	1	1	1	0	5-8
LOGICAL										
ANA r	And register with A	1	0	1	0	0	S	S	S	5-9
XRA r	Exclusive OR register with A	1	0	1	0	1	S	S	S	5-10
ORA r	OR register with A	1	0	1	1	0	S	S	S	5-10
CMP r	Compare register with A	1	0	1	1	1	S	S	S	5-11
ANA M	And memory with A	1	0	1	0	0	1	1	0	5-10
XRA M	Exclusive OR memory with A	1	0	1	0	1	1	1	0	5-10
ORA M	OR memory with A	1	0	1	1	0	1	1	0	5-11
CMP M	Compare memory with A	1	0	1	1	1	1	1	0	5-11
ANI	And immediate with A	1	1	1	0	0	1	1	0	5-10
XRI	Exclusive OR immediate with A	1	1	1	0	1	1	1	0	5-10
ORI	OR immediate with A	1	1	1	1	0	1	1	0	5-11
CPI	Compare immediate with A	1	1	1	1	1	1	1	0	5-11
ROTATE										
RLC	Rotate A left	0	0	0	0	0	1	1	1	5-11
RRC	Rotate A right	0	0	0	0	1	1	1	1	5-12
RAL	Rotate A left through carry	0	0	0	1	0	1	1	1	5-12
RAR	Rotate A right through carry	0	0	0	1	1	1	1	1	5-12
SPECIALS										
CMA	Complement A	0	0	1	0	1	1	1	1	5-12
STC	Set carry	0	0	1	1	0	1	1	1	5-12
CMC	Complement carry	0	0	1	1	1	1	1	1	5-12
DAA	Decimal adjust A	0	0	1	0	0	1	1	1	5-9
CONTROL										
EI	Enable Interrupts	1	1	1	1	1	0	1	1	5-17
DI	Disable Interrupt	1	1	1	1	0	0	1	1	5-17
NOP	No-operation	0	0	0	0	0	0	0	0	5-17
HLT	Halt	0	1	1	1	0	1	1	0	5-17
NEW 8085A INSTRUCTIONS										
RIM	Read Interrupt Mask	0	0	1	0	0	0	0	0	5-17
SIM	Set Interrupt Mask	0	0	1	1	0	0	0	0	5-18

NOTES: 1. DDS or SSS: B 000, C 001, D 010, E011, H 100, L 101, Memory 110, A 111.

2. Two possible cycle times. (6/12) indicate instruction cycles dependent on condition flags.

*All mnemonics copyrighted © Intel Corporation 1976.

8155/8156/8155-2/8156-2
2048 BIT STATIC MOS RAM WITH I/O PORTS AND TIMER

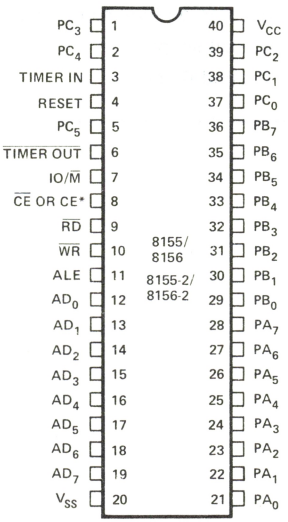
- 256 Word x 8 Bits
- Single +5V Power Supply
- Completely Static Operation
- Internal Address Latch
- 2 Programmable 8 Bit I/O Ports
- 1 Programmable 6-Bit I/O Port
- Programmable 14-Bit Binary Counter/ Timer
- Compatible with 8085A and 8088 CPU
- Multiplexed Address and Data Bus
- 40 Pin DIP

The 8155 and 89156 are RAM and I/O chips to be used in the 8085A and 8088 microprocessor systems. The RAM portion is designed with 2048 static cells organized as 256 x 8. They have a maximum access time of 400 ns to permit use with no wait states in 8085A CPU. The 8155-2 and 8156-2 have maximum access times of 330 ns for use with the 8085A-2 and the full speed 5 MHz 8088 CPU.

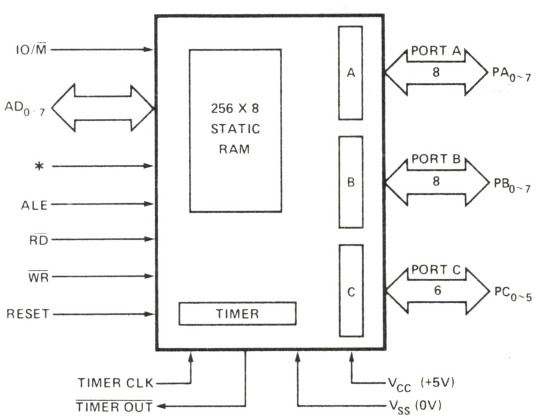
The I/O portion consists of three general purpose I/O ports. One of the three ports can be programmed to be status pins, thus allowing the other two ports to operate in handshake mode.

A 14-bit programmable counter/timer is jalso included on chip to provide either a square wave or terminal count pulse for the CPU system depending on timer mode.

PIN CONFIGURATION



BLOCK DIAGRAM



*: 8155/8155-2 = $\overline{CE}$, 8156/8156-2 = CE

8155/8156 PIN FUNCTIONS

Symbol	Function
RESET (input)	Pulse provided by the 8085A to initialize the system (connect to 8085A RESET OUT). Input high on this line resets the chip and initializes the three I/O ports to input mode. The width of RESET pulse should typically be two 8085A clock cycle times.
AD_{0-7} (input)	3-state Address/Data lines that interface with the CPU lower 8-bit Address/Data Bus. The 8-bit address is latched into the address latch inside the 8155/56 on the falling edge of ALE. The address can be either for the memory section or the I/O section depending on the IO/$\overline{M}$ input. The 8-bit data is either written into the chip or read from the chip, depending on the $\overline{WR}$ or $\overline{RD}$ input signal.
CE or $\overline{CE}$ (input)	Chip Enable: On the 8155, this pin is $\overline{CE}$ and is ACTIVE LOW. On the 8156, this pin is CE and is ACTIVE HIGH.
$\overline{RD}$ (input)	Read control: Input low on this line with the Chip Enable active enables and AD_{0-7} buffers. If IO/$\overline{M}$ pin is low, the RAM content will be read out to the AD bus. Otherwise the content of the selected I/O port or command/status registers will be read to the AD bus.
$\overline{WR}$ (input)	Write control: Input low on this line with the Chip Enable active causes the data on the Address/Data bus to be written to the RAM or I/O ports and command/status register depending on IO/$\overline{M}$.
ALE (input)	Address Latch Enable: This control signal latches both the address on the AD_{0-7} lines and the state of the Chip Enable and IO/$\overline{M}$ into the chip at the falling edge of ALE.
IO/$\overline{M}$ (input)	Selects memory if low and I/O and command/status registers if high.
PA_{0-7}(8) (input/output)	These 8 pins are general purpose I/O pins. The in/out direction is selected by programming the command register.
PB_{0-7}(8) (input/output)	These 8 pins are general purpose I/O pins. The in/out direction is selected by programming the command register.
PC_{0-5}(6) (input/output)	These 6 pins can function as either input port, output port, or as control signals for PA and PB. Programming is done through the command register. When PC_{0-5} are used as control signals, they will provide the following: PC_0 — A INTR (Port A Interrupt) PC_1 — $\overline{ABF}$ (Port A Buffer Full) PC_2 — $\overline{A\ STB}$ (Port A Strobe) PC_3 — B INTR (Port B Interrupt) PC_4 — $\overline{B\ BF}$ (Port B Buffer Full) PC_5 — B STB (Port B Strobe)
TIMER IN (input)	Input to the counter-timer.
$\overline{TIMER\ OUT}$ (output)	Timer output. This output can be either a square wave or a pulse depending on the timer mode.
V_{CC}	+5 volt supply.
V_{SS}	Ground Reference.

DESCRIPTION

The 8155/8156 contains the following:

- 2k Bit Static RAM organized as 256 x 8
- Two 8-bit I/O ports (PA & PB) and one 6-bit I/O port (PC)
- 14-bit timer-counter

The IO/$\overline{M}$ (IO/Memory Select) pin selects either the five registers (Command, Status, PA_{0-7}, PB_{0-7}, PC_{0-5}) or the memory (RAM) portion. (See Figure 1.)

The 8-bit address on the Address/Data lines, Chip Enable input CE or $\overline{CE}$, and IO/$\overline{M}$ are all latched on-chip at the falling edge of ALE. (See Figure 2.)

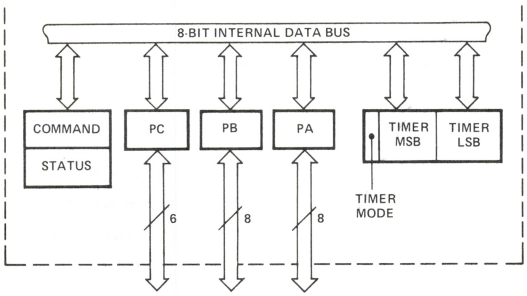
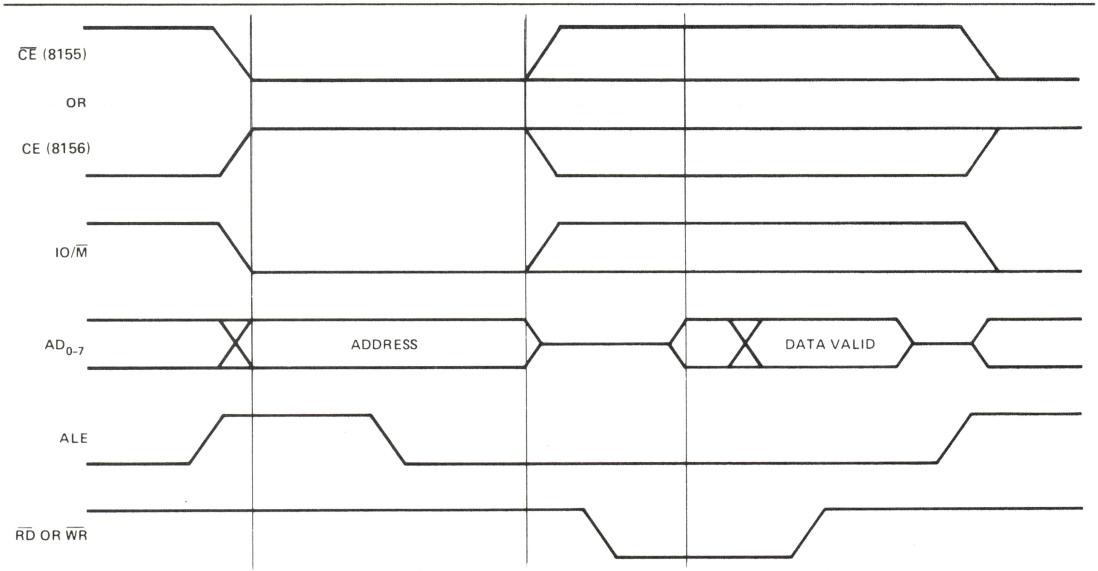


Figure 1. 8155/8156 Internal Registers



NOTE: FOR DETAILED TIMING INFORMATION, SEE FIGURE 12 AND A.C. CHARACTERISTICS.

Figure 2. 8155/8156 On-Board Memory Read/Write Cycle

PROGRAMMING OF THE COMMAND REGISTER

The command register consists of eight latches. Four bits (0-3) define the mode of the ports, two bits (4-5) enable or disable the interrupt from port C when it acts as control port, and the last two bits (6-7) are for the timer.

The command register contents can be altered at any time by using the I/O address XXXXX000 during a WRITE operation with the Chip Enable active and IO/$\overline{M}$ = 1. The meaning of each bit of the command byte is defined in Figure 3. The contents of the command register may never be read.

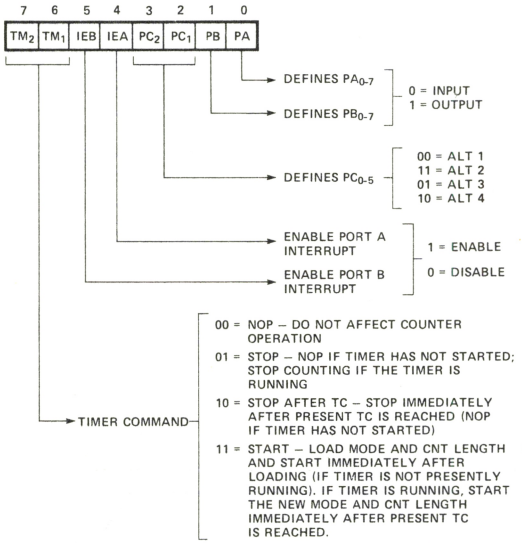


Figure 3. Command Register Bit Assignment

READING THE STATUS REGISTER

The status register consists of seven latches, one for each bit; six (0-5) for the status of the ports and one (6) for the status of the timer.

The status of the timer and the I/O section can be polled by reading the Status Register (Address XXXXX000). Status word format is shown in Figure 4. Note that you may never write to the status register since the command register shares the same I/O address and the command register is selected when a write to that address is issued.

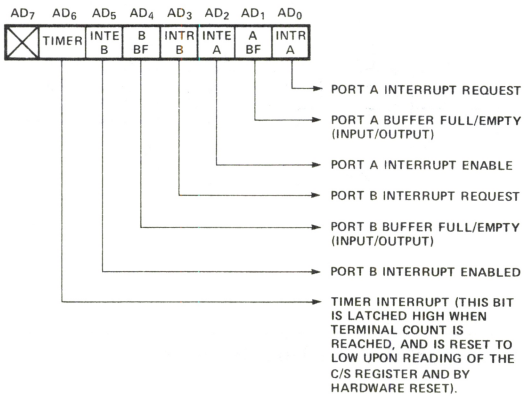


Figure 4. Status Register Bit Assignment

INPUT/OUTPUT SECTION

The I/O section of the 8155/8156 consists of five registers: (See Figure 5.)

- **Command/Status Register (C/S)** — Both registers are assigned the address XXXXX000. The C/S address serves the dual purpose.

  When the C/S registers are selected during WRITE operation, a command is written into the command register. The contents of this register are *not* accessible through the pins.

  When the C/S (XXXXX000) is selected during a READ operation, the status information of the I/O ports and the timer becomes available on the AD_{0-7} lines.

- **PA Register** — This register can be programmed to be either input or output ports depending on the status of the contents of the C/S Register. Also depending on the command, this port can operate in either the basic mode or the strobed mode (See timing diagram). The I/O pins assigned in relation to this register are PA_{0-7}. The address of this register is XXXXX001.

- **PB Register** — This register functions the same as PA Register. The I/O pins assigned are PB_{0-7}. The address of this register is XXXXX010.

- **PC Register** — This register has the address XXXXX011 and contains only 6 bits. The 6 bits can be programmed to be either input ports, output ports or as control signals for PA and PB by properly programming the AD_2 and AD_3 bits of the C/S register.

  When PC_{0-5} is used as a control port, 3 bits are assigned for Port A and 3 for Port B. The first bit is an interrupt that the 8155 sends out. The second is an output signal indicating whether the buffer is full or empty, and the third is an input pin to accept a strobe for the strobed input mode. (See Table 1.)

When the 'C' port is programmed to either ALT3 or ALT4, the control signals for PA and PB are initialized as follows:

CONTROL	INPUT MODE	OUTPUT MODE
BF	Low	Low
INTR	Low	High
STB	Input Control	Input Control

I/O ADDRESS†								SELECTION
A7	A6	A5	A4	A3	A2	A1	A0	
X	X	X	X	X	0	0	0	Interval Command/Status Register
X	X	X	X	X	0	0	1	General Purpose I/O Port A
X	X	X	X	X	0	1	0	General Purpose I/O Port B
X	X	X	X	X	0	1	1	Port C — General Purpose I/O or Control
X	X	X	X	X	1	0	0	Low-Order 8 bits of Timer Count
X	X	X	X	X	1	0	1	High 6 bits of Timer Count and 2 bits of Timer Mode

X: Don't Care.
†: I/O Address must be qualified by CE = 1 (8156) or $\overline{CE}$ = 0 (8155) and IO/$\overline{M}$ = 1 in order to select the appropriate register.

Figure 5. I/O port and Timer Addressing Scheme

Figure 6 shows how I/O PORTS A and B are structured within the 8155 and 8156:

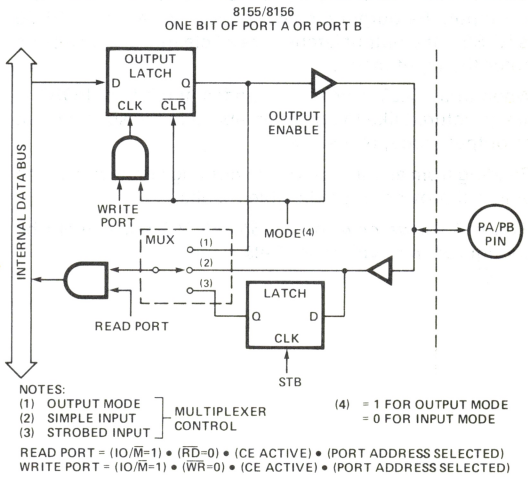


Figure 6. 8155/8156 Port Functions

TABLE 1. TABLE OF PORT CONTROL ASSIGNMENT.

Pin	ALT 1	ALT 2	ALT 3	ALT 4
PC0	Input Port	Output Port	A INTR (Port A Interrupt)	A INTR (Port A Interrupt)
PC1	Input Port	Output Port	A BF (Port A Buffer Full)	A BF (Port A Buffer Full)
PC2	Input Port	Output Port	A $\overline{\text{STB}}$ (Port A Strobe)	A $\overline{\text{STB}}$ (Port A Strobe)
PC3	Input Port	Output Port	Output Port	B INTR (Port B Interrupt)
PC4	Input Port	Output Port	Output Port	B BF (Port B Buffer Full)
PC5	Input Port	Output Port	Output Port	B $\overline{\text{STB}}$ (Port B Strobe)

Note in the diagram that when the I/O ports are programmed to be output ports, the contents of the output ports can still be read by a READ operation when appropriately addressed.

The outputs of the 8155/8156 are "glitch-free" meaning that you can write a "1" to a bit position that was previously "1" and the level at the output pin will not change.

Note also that the output latch is cleared when the port enters the input mode. The output latch cannot be loaded by writing to the port if the port is in the input mode. The result is that each time a port mode is changed from input to output, the output pins will go low. When the 8155/56 is RESET, the output latches are all cleared and all 3 ports enter the input mode.

When in the ALT 1 or ALT 2 modes, the bits of PORT C are structured like the diagram above in the simple input or output mode, respectively.

Reading from an input port with nothing connected to the pins will provide unpredictable results.

Figure 7 shows how the 8155/8156 I/O ports might be configured in a typical MCS-85 system.

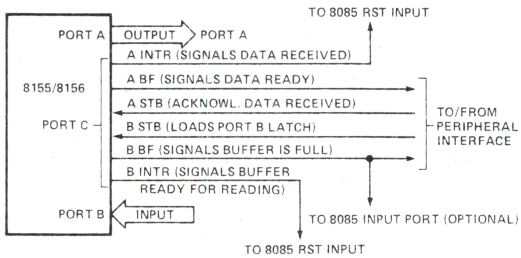


Figure 7. Example: Command Register = 00111001

TIMER SECTION

The timer is a 14-bit down-counter that counts the TIMER IN pulses and provides either a square wave or pulse when terminal count (TC) is reached.

The timer has the I/O address XXXXX100 for the low order byte of the register and the I/O address XXXXX101 for the high order byte of the register. (See Figure 5).

To program the timer, the COUNT LENGTH REG is loaded first, one byte at a time, by selecting the timer addresses. Bits 0-13 of the high order count register will specify the length of the next count and bits 14-15 of the high order register will specify the timer output mode (see Figure 8). The value loaded into the count length register can have any value from 2H through 3FFH in Bits 0-13.

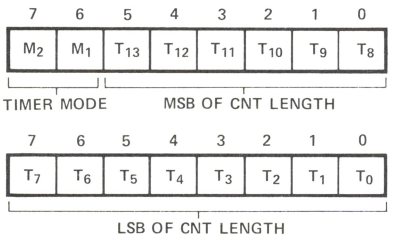


Figure 8. Timer Format

There are four modes to choose from: M2 and M1 define the timer mode, as shown in Figure 9.

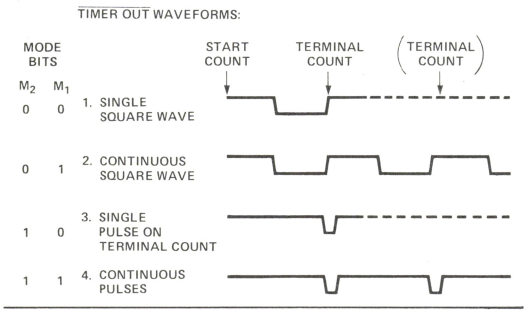


Figure 9. Timer Modes

Bits 6-7 (TM_2 and TM_1) of command register contents are used to start and stop the counter. There are four commands to choose from:

TM_2	TM_1	
0	0	NOP — Do not affect counter operation.
0	1	STOP — NOP if timer has not started; stop counting if the timer is running.
1	0	STOP AFTER TC — Stop immediately after present TC is reached (NOP if timer has not started)
1	1	START — Load mode and CNT length and start immediately after loading (if timer is not presently running). If timer is running, start the new mode and CNT length immediately after present TC is reached.

Note that while the counter is counting, you may load a new count and mode into the count length registers. Before the new count and mode will be used by the counter, you must issue a START command to the counter. This applies even though you may only want to change the count and use the previous mode.

In case of an odd-numbered count, the first half-cycle of the squarewave output, which is high, is one count longer than the second (low) half-cycle, as shown in Figure 10.

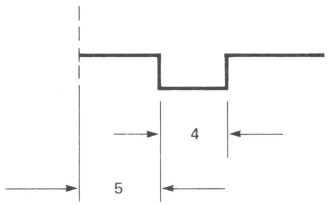


Figure 10. Asymmetrical Square-Wave Output Resulting from Count of 9

The counter in the 8155 is not initialized to any particular mode or count when hardware RESET occurs, but RESET does *stop* the counting. Therefore, counting cannot begin following RESET until a START command is issued via the C/S register.

Please note that the timer circuit on the 8155/8156 chip is designed to be a square-wave timer, not an event counter. To achieve this, it counts down by twos twice in completing one cycle. Thus, its registers do not contain values directly representing the number of TIMER IN pulses received. You cannot load an initial value of 1 into the count register and cause the timer to operate, as its terminal count value is 10 (binary) or 2 (decimal). (For the detection of single pulses, it is suggested that one of the hardware interrupt pins on the 8085A be used.) After the timer has started counting down, the values residing in the count registers can be used to calculate the actual number of TIMER IN pulses required to complete the timer cycle if desired. To obtain the remaining count, perform the following operations in order:

1. Stop the count
2. Read in the 16-bit value from the count length registers
3. Reset the upper two mode bits
4. Reset the carry and rotate right one position all 16 bits through carry
5. If carry is set, add 1/2 of the full original count (1/2 full count — 1 if full count is odd).

Note: If you started with an odd count and you read the count length register before the third count pulse occurs, you will not be able to discern whether one or two counts has occurred. Regardless of this, the 8155/56 always counts out the right number of pulses in generating the TIMER OUT waveforms.

EXAMPLE PROGRAM

Following is an actual sequence of program steps that adjusts the 8155/56 count register contents to obtain the count, extracted from Intel® Application Note AP38. "Application Techniques for the Intel 8085A Bus." First store the value of the full original count in register HL of the 8085A. Then stop the count to avoid getting an incorrect count value. Then sample the timer-counter, storing the lower-order byte of the current count register in register C and the higher-order count byte in register B. Then, call the following 8080A/8085A subroutine:

```
ADJUST, 78      MOV A,B     ;Load accumulator with upper half
                            ; of count.
        E63F    ANI 3F      ;Reset upper 2 bits and clear carry.
        1F      RAR         ;Rotate right through carry.
        47      MOV B,A     ;Store shifted value back in B.
        79      MOV A,C     ;Load accumulator with lower half.
        1F      RAR         ;Rotate right through carry.
        4F      MOV C,A     ;Store lower byte in C.
        DØ      RNC         ;If in 2nd half of count, return.
                            ;If in 1st half, go on.
        3F      CMC         ;Clear carry.
        7C      MOV A,H     ;Divide full count by 2. (If HL
                            ;is odd, disregard remainder.)
        1F      RAR
        67      MOV H,A
        7D      MOV A,L
        1F      RAR
        6F      MOV L,A
        09      DAD B       ;Double-precision add HL and BC.
        44      MOV B,H     ;Store results back in BC.
        4D      MOV C,L
        C9      RET         ;Return.
```

After executing the subroutine, BC will contain the remaining count in the current count cycle.

8085A MINIMUM SYSTEM CONFIGURATION

Figure 11a shows a minimum system using three chips, containing:

- 256 Bytes RAM
- 2K Bytes ROM
- 38 I/O Pins
- 1 Interval Timer
- 4 Interrupt Levels

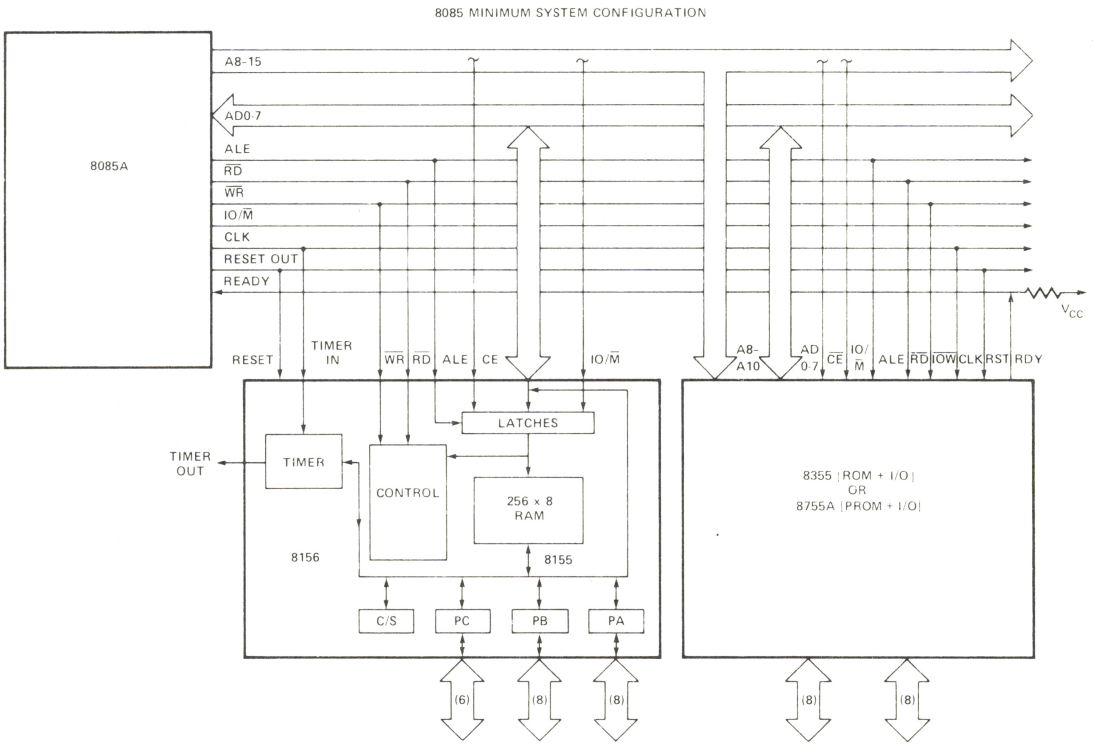


Figure 11a. 8085A Minimum System Configuration. (Memory Mapped I/O)

8088 FIVE CHIP SYSTEM

Figure 11b shows a five chip system containing:

- 1.25K Bytes RAM
- 2K Bytes ROM
- 38 I/O Pins
- 1 Interval Timer
- 2 Interrupt Levels

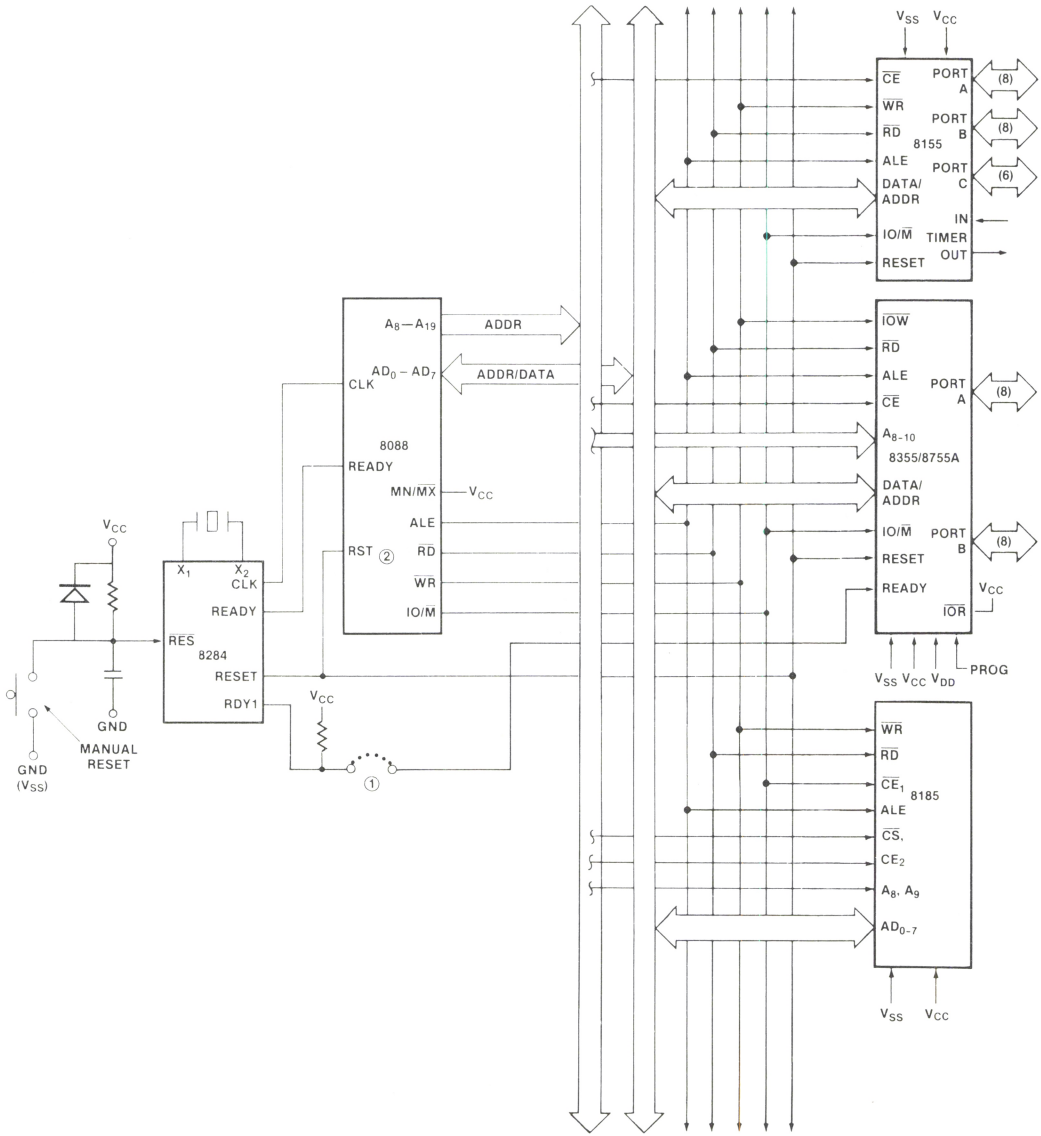


Figure 11b. 8088 Five Chip System Configuration

ABSOLUTE MAXIMUM RATINGS*

Temperature Under Bias ..... 0°C to +70°C
Storage Temperature ..... -65°C to +150°C
Voltage on Any Pin
With Respect to Ground ..... -0.5V to +7V
Power Dissipation 1.5W

**COMMENT: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

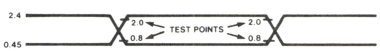
D.C. CHARACTERISTICS (T_A = 0°C to 70°C; V_{CC} = 5V ± 5%)

SYMBOL	PARAMETER	MIN.	MAX.	UNITS	TEST CONDITIONS
V_{IL}	Input Low Voltage	-0.5	0.8	V	
V_{IH}	Input High Voltage	2.0	V_{CC}+0.5	V	
V_{OL}	Output Low Voltage		0.45	V	I_{OL} = 2mA
V_{OH}	Output High Voltage	2.4		V	I_{OH} = -400μA
I_{IL}	Input Leakage		±10	μA	V_{IN} = V_{CC} to 0V
I_{LO}	Output Leakage Current		± 10	μA	0.45V ≤ V_{OUT} ≤ V_{CC}
I_{CC}	V_{CC} Supply Current		180	mA	
I_{IL}(CE)	Chip Enable Leakage 8155 8156		 +100 -100	 μA μA	V_{IN} = V_{CC} to 0V

A.C. CHARACTERISTICS (T_A = 0°C to 70°C; V_{CC} = 5V ± 5%)

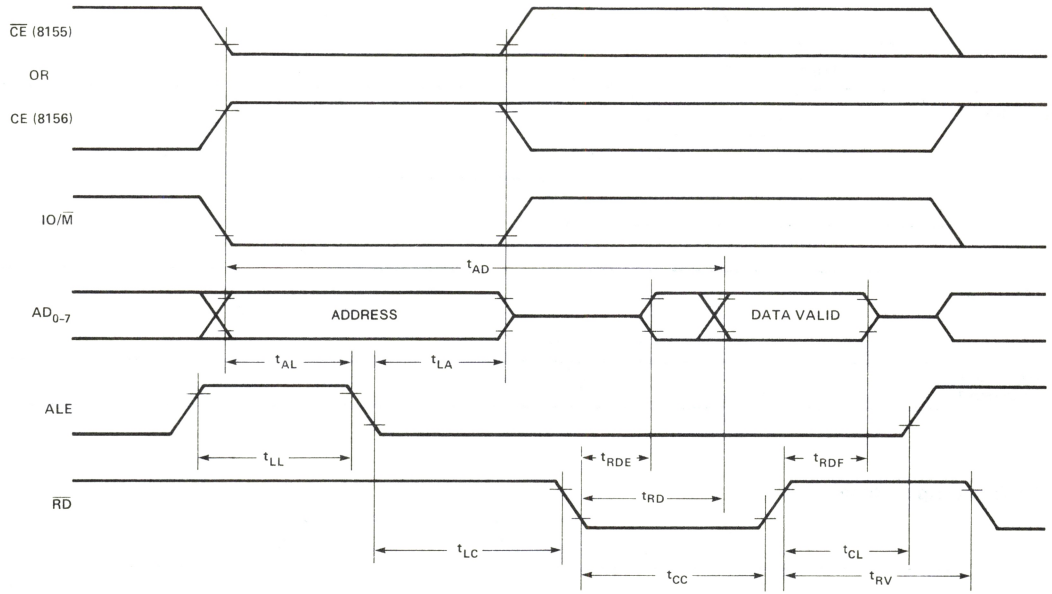
		8155/8156		8155-2/8156-2 (Preliminary)		
SYMBOL	PARAMETER	MIN.	MAX.	MIN.	MAX.	UNITS
t_{AL}	Address to Latch Set Up Time	50		30		ns
t_{LA}	Address Hold Time after Latch	80		30		ns
t_{LC}	Latch to READ/WRITE Control	100		40		ns
t_{RD}	Valid Data Out Delay from READ Control		170		140	ns
t_{AD}	Address Stable to Data Out Valid		400		330	ns
t_{LL}	Latch Enable Width	100		70		ns
t_{RDF}	Data Bus Float After READ	0	100	0	80	ns
t_{CL}	READ/WRITE Control to Latch Enable	20		10		ns
t_{CC}	READ/WRITE Control Width	250		200		ns
t_{DW}	Data In to WRITE Set Up Time	150		100		ns
t_{WD}	Data In Hold Time After WRITE	0		0		ns
t_{RV}	Recovery Time Between Controls	300		200		ns
t_{WP}	WRITE to Port Output		400		300	ns
t_{PR}	Port Input Setup Time	70		50		ns
t_{RP}	Port Input Hold Time	50		10		ns
t_{SBF}	Strobe to Buffer Full		400		300	ns
t_{SS}	Strobe Width	200		150		ns
t_{RBE}	READ to Buffer Empty		400		300	ns
t_{SI}	Strobe to INTR On		400		300	ns
t_{RDI}	READ to INTR Off		400		300	ns
t_{PSS}	Port Setup Time to Strobe Strobe	50		0		ns
t_{PHS}	Port Hold Time After Strobe	120		100		ns
t_{SBE}	Strobe to Buffer Empty		400		300	ns
t_{WBF}	WRITE to Buffer Full		400		300	ns
t_{WI}	WRITE to INTR Off		400		300	ns
t_{TL}	TIMER-IN to $\overline{\text{TIMER-OUT}}$ Low		400		300	ns
t_{TH}	TIMER-IN to $\overline{\text{TIMER-OUT}}$ High		400		300	ns
t_{RDE}	Data Bus Enable from READ Control	10		10		ns
t_1	TIMER-IN Low Time	80		40		ns
t_2	TIMER-IN High Time	120		70		ns

Input Waveform for A.C. Tests:



WAVEFORMS

a. Read Cycle



b. Write Cycle

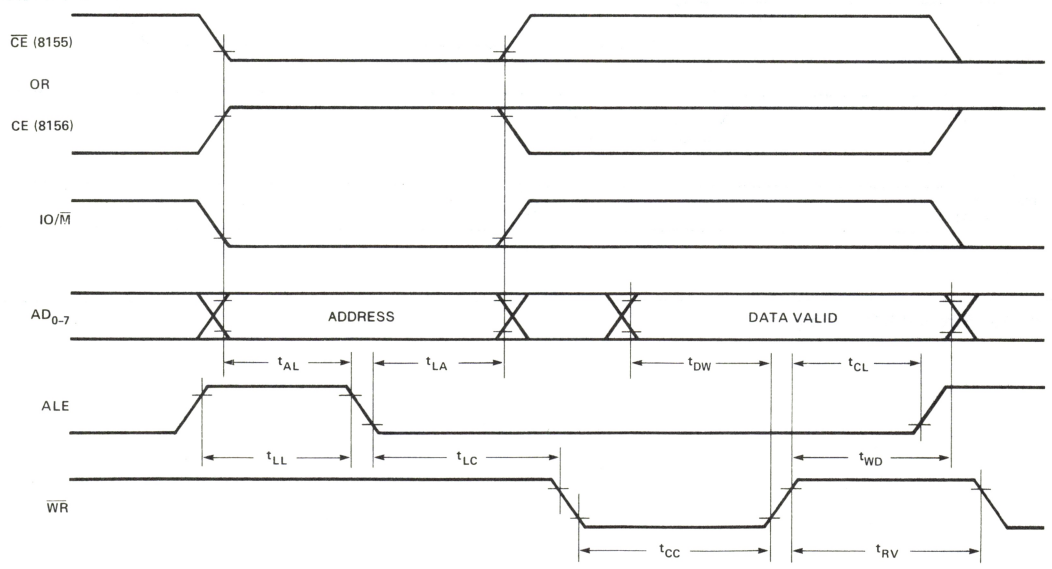
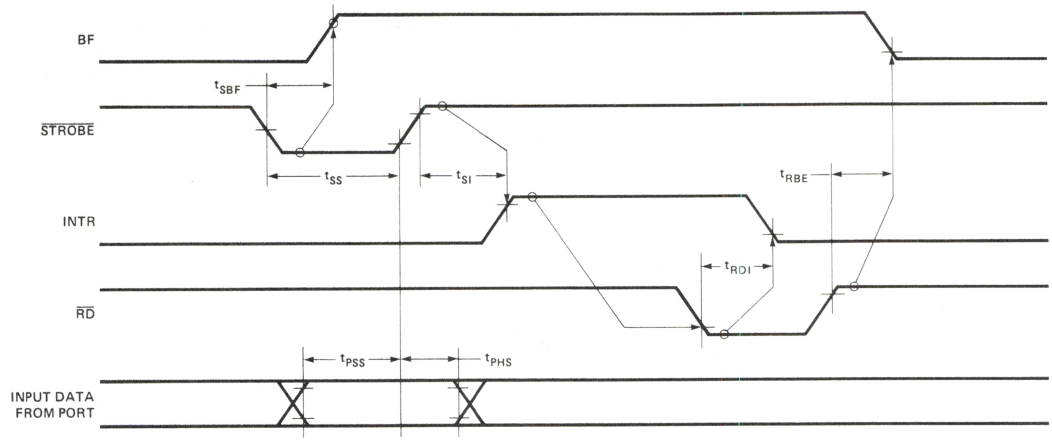


Figure 12. 8155/8156 Read/Write Timing Diagrams

a. Strobed Input Mode



b. Strobed Output Mode

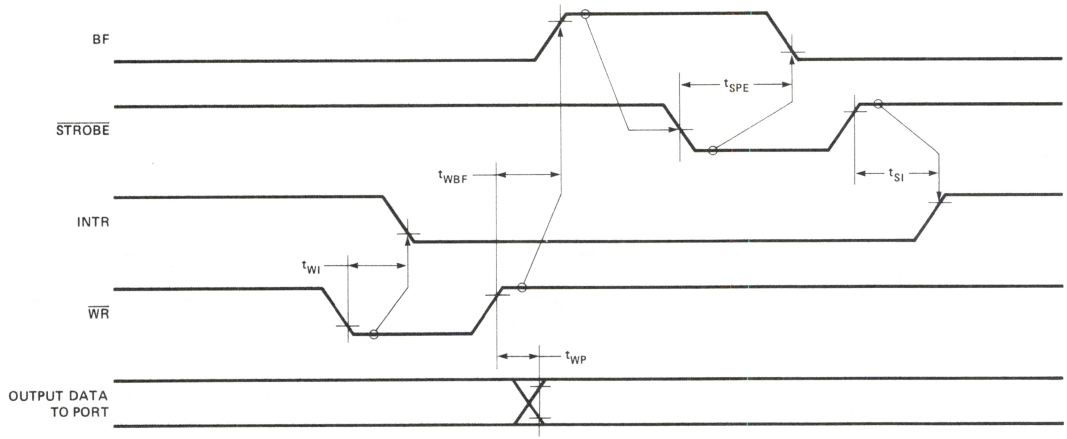
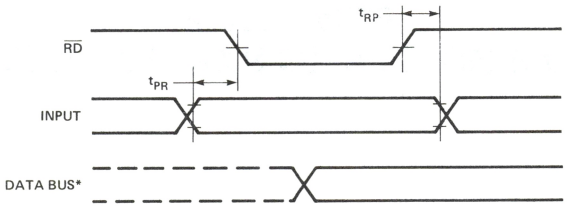
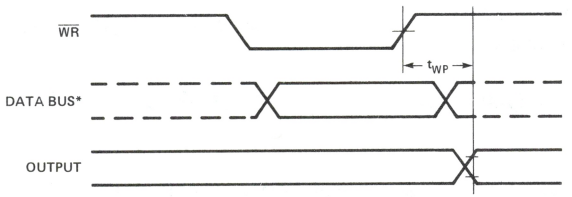


Figure 13. Strobed I/O Timing

a. Basic Input Mode

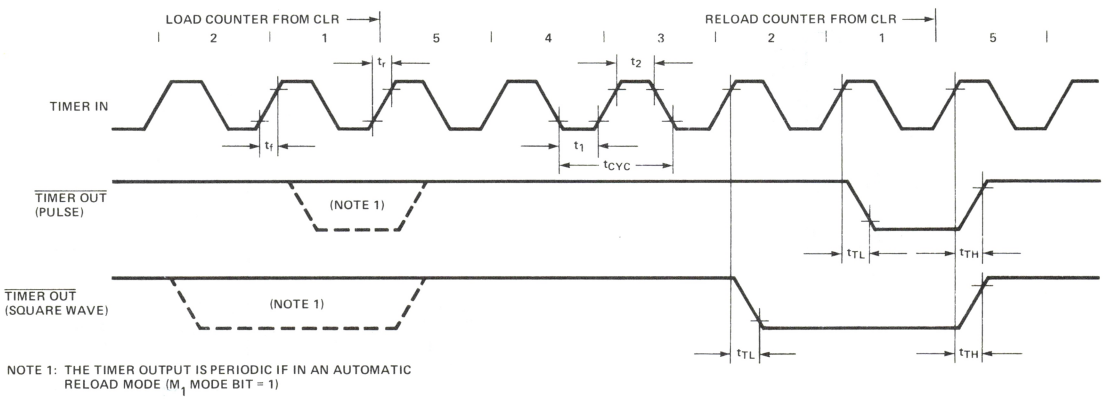


b. Basic Output Mode



*DATA BUS TIMING IS SHOWN IN FIGURE 7.

Figure 14. Basic I/O Timing Waveform



NOTE 1: THE TIMER OUTPUT IS PERIODIC IF IN AN AUTOMATIC RELOAD MODE (M_1 MODE BIT = 1)

Figure 15. Timer Output Waveform Countdown from 5 to 1

PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

8185/8185-2
1024 x 8-BIT STATIC RAM FOR MCS-85™

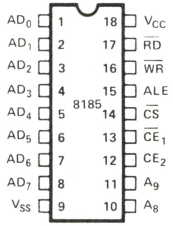
- **Multiplexed Address and Data Bus**
- **Directly Compatible with 8085A and 8088 Microprocessors**
- **Low Operating Power Dissipation**
- **Low Standby Power Dissipation**
- **Single +5V Supply**
- **High Density 18-Pin Package**

The Intel® 8185 is an 8192-bit static random access memory (RAM) organized as 1024 words by 8-bits using N-channel Silicon-Gate MOS technology. The multiplexed address and data bus allows the 8185 to interface directly to the 8085A and 8088 microprocessors to provide a maximum level of system integration.

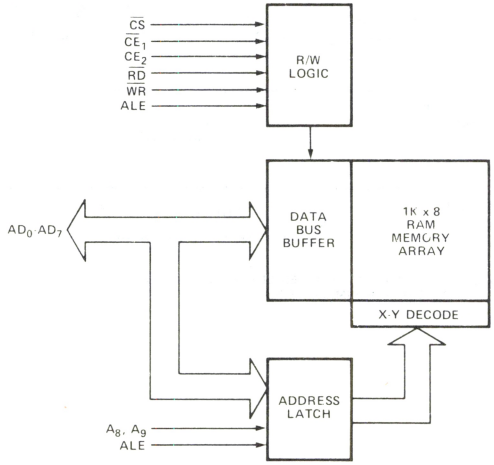
The low standby power dissipation minimizes system power requirements when the 8185 is disabled.

The 8185-2 is a high-speed selected version of the 8185 that is compatible with the 5 MHz 8085A-2 and the full speed 5 MHz 8088.

PIN CONFIGURATION



BLOCK DIAGRAM



PIN NAMES

AD_0-AD_7	ADDRESS/DATA LINES
A_8, A_9	ADDRESS LINES
$\overline{CS}$	CHIP SELECT
$\overline{CE}_1$	CHIP ENABLE (IO/$\overline{M}$)
CE_2	CHIP ENABLE
ALE	ADDRESS LATCH ENABLE
$\overline{RD}$	READ ENABLE
$\overline{WR}$	WRITE ENABLE

PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

OPERATIONAL DESCRIPTION

The 8185 has been designed to provide for direct interface to the multiplexed bus structure and bus timing of the 8085A microprocessor.

At the beginning of an 8185 memory access cycle, the 8-bit address on AD_{0-7}, A_8 and A_9, and the status of $\overline{CE}_1$ and CE_2 are all latched internally in the 8185 by the falling edge of ALE. If the latched status of both $\overline{CE}_1$ and CE_2 are active, the 8185 powers itself up, but no action occurs until the $\overline{CS}$ line goes low and the appropriate $\overline{RD}$ or $\overline{WR}$ control signal input is activated.

The $\overline{CS}$ input is not latched by the 8185 in order to allow the maximum amount of time for address decoding in selecting the 8185 chip. Maximum power consumption savings will occur, however, only when $\overline{CE}_1$ and CE_2 are activated selectively to power down the 8185 when it is not in use. A possible connection would be to wire the 8085A's IO/$\overline{M}$ line to the 8185's $\overline{CE}_1$ input, thereby keeping the 8185 powered down during I/O and interrupt cycles.

TABLE 1.
TRUTH TABLE FOR
POWER DOWN AND FUNCTION ENABLE

$\overline{CE}_1$	CE_2	$\overline{CS}$	(CS*)[2]	8185 Status
1	X	X	0	Power Down and Function Disable[1]
X	0	X	0	Power Down and Function Disable[1]
0	1	1	0	Powered Up and Function Disable[1]
0	1	0	1	Powered Up and Enabled

Notes:
X: Don't Care.
1: Function Disable implies Data Bus in high impedance state and not writing.
2: CS* = $(\overline{CE}_1 = 0) \bullet (CE_2 = 1) \bullet (\overline{CS} = 0)$
CS* = 1 signifies all chip enables and chip select active

TABLE 2.
TRUTH TABLE FOR
CONTROL AND DATA BUS PIN STATUS

(CS*)	$\overline{RD}$	$\overline{WR}$	AD_{0-7} During Data Portion of Cycle	8185 Function
0	X	X	Hi-Impedance	No Function
1	0	1	Data from Memory	Read
1	1	0	Data to Memory	Write
1	1	1	Hi-Impedance	Reading, but not Driving Data Bus

Note:
X: Don't Care.

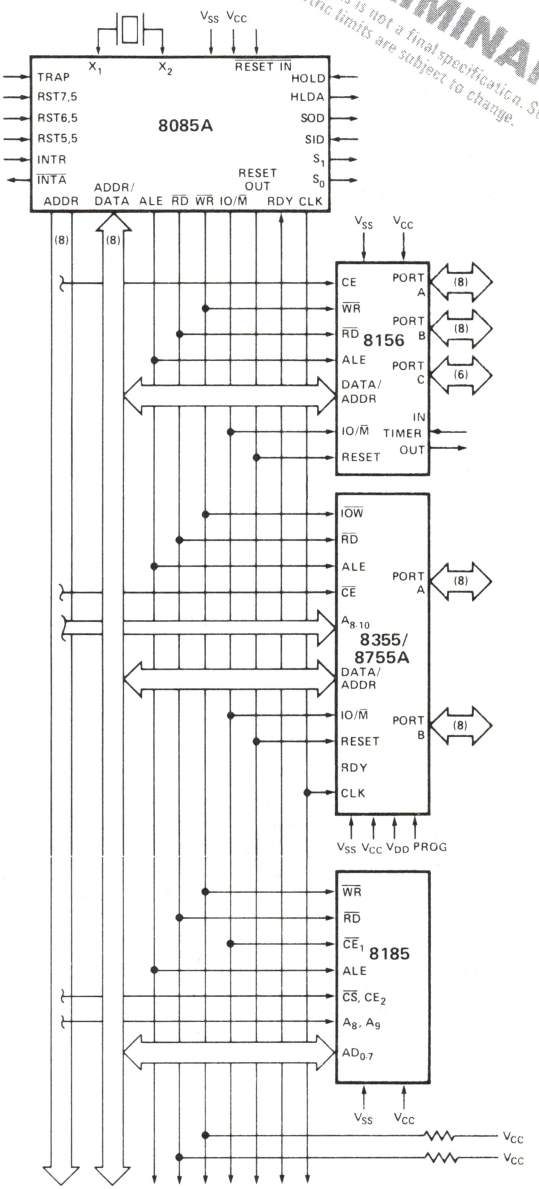


Figure 1. 8185 in an MCS-85 System.

4 Chips:
2K Bytes ROM
1.25K Bytes RAM
38 I/O Lines
1 Counter/Timer
2 Serial I/O Lines
5 Interrupt Inputs

PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

8088 FIVE CHIP SYSTEM

Figure 2 shows a five chip system containing:

- 1.25 K Bytes RAM
- 2 K Bytes ROM
- 38 I/O Pins
- 1 Interval Timer
- 2 Interrupt Levels

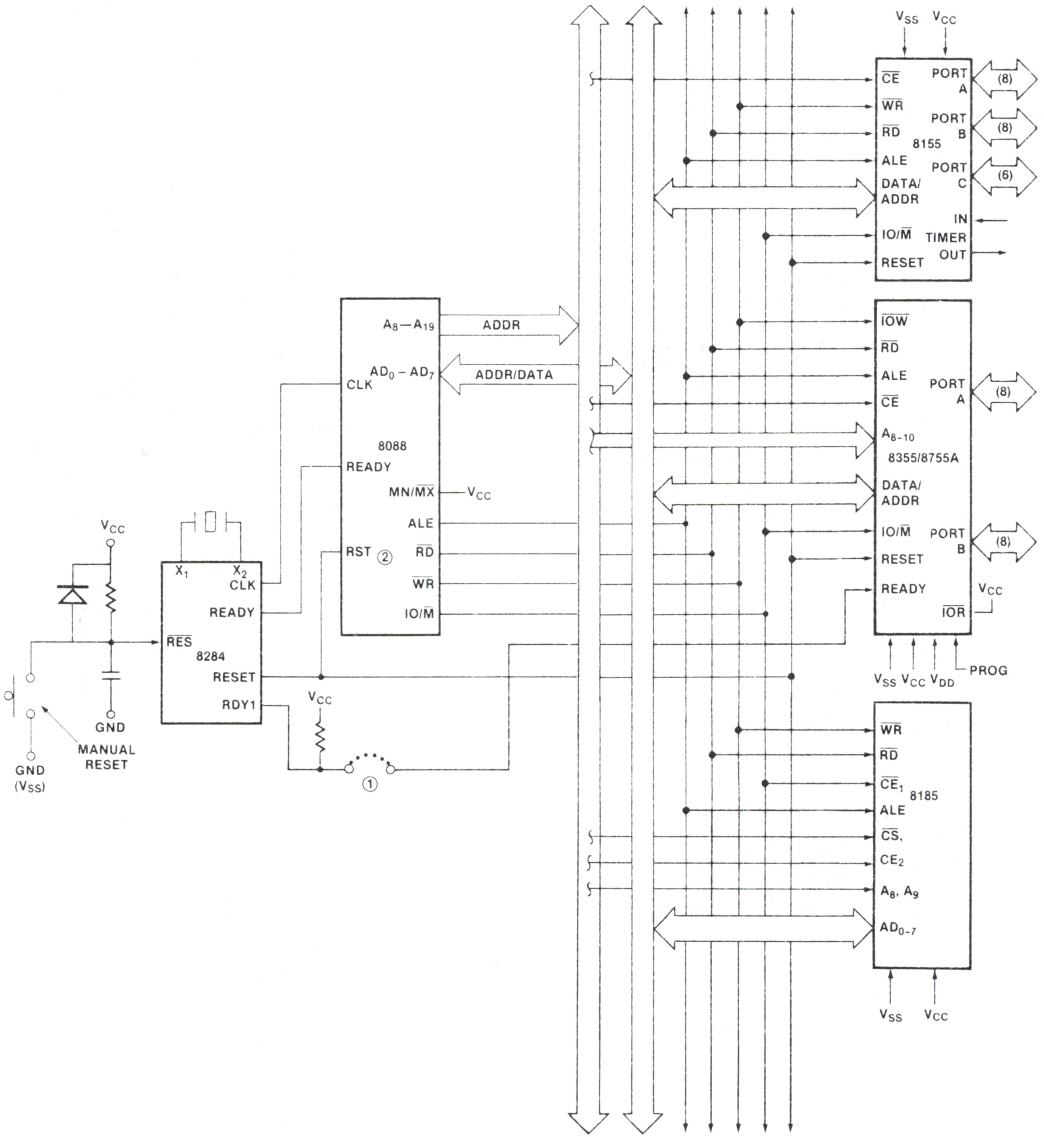


Figure 2. 8088 Five Chip System Configuration.

PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

ABSOLUTE MAXIMUM RATINGS*

Temperature Under Bias ..... 0°C to +70°C
Storage Temperature ..... -65°C to +150°C
Voltage on Any Pin
with Respect to Ground ..... -0.5V to +7V
Power Dissipation 1.5W

*COMMENT

Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

D.C. CHARACTERISTICS (T_A = 0°C to 70°C; V_{CC} = 5V ± 5%)

Symbol	Parameter	Min.	Max.	Units	Test Conditions
V_{IL}	Input Low Voltage	-0.5	0.8	V	
V_{IH}	Input High Voltage	2.0	V_{CC}+0.5	V	
V_{OL}	Output Low Voltage		0.45	V	I_{OL} = 2mA
V_{OH}	Output High Voltage	2.4			I_{OH} = 400μA
I_{IL}	Input Leakage		±10	μA	V_{IN} = V_{CC} to 0V
I_{LO}	Output Leakage Current		±10	μA	0.45V ≤ V_{OUT} ≤ V_{CC}
I_{CC}	V_{CC} Supply Current Powered Up		100	mA	
	Powered Down		25	mA	

A.C. CHARACTERISTICS (T_A = 0°C to 70°C; V_{CC} = 5V ± 5%)

Symbol	Parameter [1]	8185 Preliminary		8185-2 Preliminary		Units
		Min.	Max.	Min.	Max.	
t_{AL}	Address to Latch Set Up Time	50		30		ns
t_{LA}	Address Hold Time After Latch	80		30		ns
t_{LC}	Latch to READ/WRITE Control	100		40		ns
t_{RD}	Valid Data Out Delay from READ Control		170		140	ns
t_{LD}	ALE to Data Out Valid		300		200	ns
t_{LL}	Latch Enable Width	100		70		ns
t_{RDF}	Data Bus Float After READ	0	100	0	80	ns
t_{CL}	READ/WRITE Control to Latch Enable	20		10		ns
t_{CC}	READ/WRITE Control Width	250		200		ns
t_{DW}	Data In to WRITE Set Up Time	150		150		ns
t_{WD}	Data In Hold Time After WRITE	20		20		ns
t_{SC}	Chip Select Set Up to Control Line	10		10		ns
t_{CS}	Chip Select Hold Time After Control	10		10		ns
t_{ALCE}	Chip Enable Set Up to ALE Falling	30		10		ns
t_{LACE}	Chip Enable Hold Time After ALE	50		30		ns

Notes:
1. All AC parameters are referenced at
   a) 2.4V and .45V for inputs
   b) 2.0V and .8V for outputs.

Input Waveform for A.C. Tests:



PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

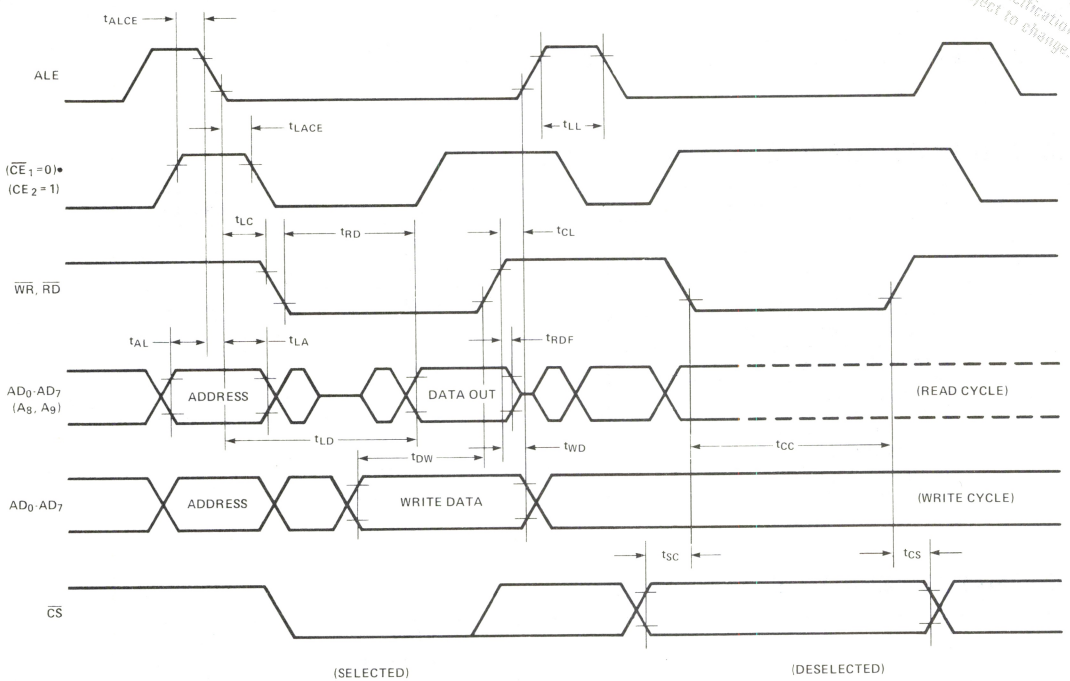


Figure 3. 8185 Timing.

8355/8355-2
16,384-BIT ROM WITH I/O

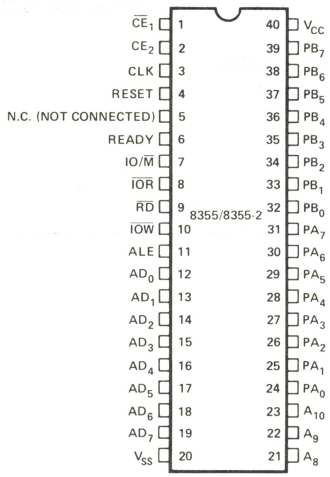
- 2048 Words x 8 Bits
- Single +5V Power Supply
- Directly compatible with 8085A and 8088 Microprocessors
- 2 General Purpose 8-Bit I/O Ports
- Each I/O Port Line Individually Programmable as Input or Output
- Multiplexed Address and Data Bus
- Internal Address Latch
- 40-Pin DIP

The Intel® 8355 is a ROM and I/O chip to be used in the 8085A and 8088 microprocessor systems. The ROM portion is organized as 2048 words by 8 bits. It has a maximum acess time of 400 ns to permit use with no wait states in the 8085A CPU.

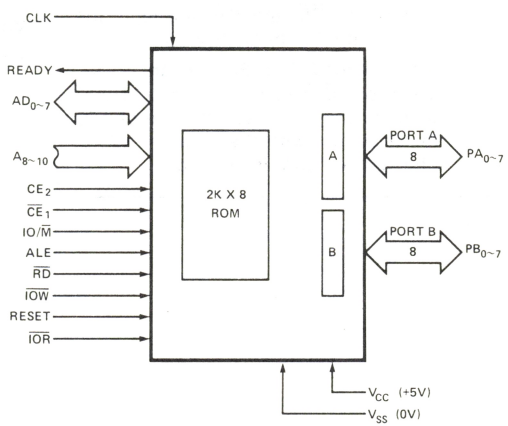
The I/O portion consists of 2 general purpose I/O ports. Each I/O port has 8 port lines and each I/O port line is individually programmable as input or output.

The 8355-2 has a 300ns access time for compatibility with the 8085A-2 and full speed 5 MHz 8088 microprocessors.

PIN CONFIGURATION



BLOCK DIAGRAM



Symbol	Function
ALE (Input)	When ALE (Address Latch Enable is high, AD_{0-7}, IO/$\overline{M}$, A_{8-10}, CE, and $\overline{CE}$ enter address latched. The signals (AD, IO/$\overline{M}$, A_{8-10}, CE, $\overline{CE}$) are latched in at the trailing edge of ALE.
AD_{0-7} (Input)	Bidirectional Address/Data bus. The lower 8-bits of the ROM or I/O address are applied to the bus lines when ALE is high. During an I/O cycle, Port A or B are selected based on the latched value of AD_0. If $\overline{RD}$ or $\overline{IOR}$ is low when the latched chip enables are active, the output buffers present data on the bus.
A_{8-10} (Input)	These are the high order bits of the ROM address. They do not affect I/O operations.
$\overline{CE_1}$ CE_2 (Input)	Chip Enable Inputs: $\overline{CE_1}$ is active low and CE_2 is active high. The 8355 can be accessed only when BOTH Chip Enables are active at the time the ALE signal latches them up. If either Chip Enable input is not active, the AD_{0-7} and READY outputs will be in a high impedance state.
IO/$\overline{M}$ (Input)	If the latched IO/$\overline{M}$ is high when $\overline{RD}$ is low, the output data comes from an I/O port. If it is low the output data comes from the ROM.
$\overline{RD}$ (Input)	If the latched Chip Enables are active when $\overline{RD}$ goes low, the AD_{0-7} output buffers are enabled and output either the selected ROM location or I/O port. When both $\overline{RD}$ and $\overline{IOR}$ are high, the AD_{0-7} output buffers are 3-state.
$\overline{IOW}$ (Input)	If the latched Chip Enables are active, a low on $\overline{IOW}$ causes the output port pointed to by the latched value of AD_0 to be written with the data on AD_{0-7}. The state of IO/$\overline{M}$ is ignored.

Symbol	Function
CLK (Input)	The CLK is used to force the READY into its high impedance state after it has been forced low by $\overline{CE}$ low, CE high and ALE high.
READY (Output)	Ready is a 3-state output controlled by $\overline{CE_1}$, CE_2, ALE and CLK. READY is forced low when the Chip Enables are active during the time ALE is high, and remains low until the rising edge of the next CLK (see Figure 6).
PA_{0-7} (Input/ Output)	These are general purpose I/O pins. Their input/output direction is determined by the contents of Data Direction Register (DDR). Port A is selected for write operations when the Chip Enables are active and $\overline{IOW}$ is low and a 0 was previously latched from AD_0. Read operation is selected by either $\overline{IOR}$ low and active Chip Enables and AD_0 low, or IO/$\overline{M}$ high, $\overline{RD}$ low, active chip enables, and AD_0 low.
PB_{0-7} (Input/ Output)	This general purpose I/O port is identical to Port A except that it is selected by a 1 latched from AD_0.
RESET (Input)	An input high on RESET causes all pins in Port A and B to assume input mode.
$\overline{IOR}$ (Input)	When the Chip Enables are active, a low on $\overline{IOR}$ will output the selected I/O port onto the AD bus. $\overline{IOR}$ low performs the same function as the combination IO/$\overline{M}$ high and $\overline{RD}$ low. When $\overline{IOR}$ is not used in a system, $\overline{IOR}$ should be tied to V_{CC} ("1").
V_{CC}	+5 volt supply.
V_{SS}	Ground Reference.

FUNCTIONAL DESCRIPTION

ROM Section

The 8355 contains an 8-bit address latch which allows it to interface directly to MCS-48 and MCS-85 Microcomputers without additional hardware.

The ROM section of the chip is addressed by an 11-bit address and the Chip Enables. The address and levels on the Chip Enable pins are latched into the address latches on the falling edge of ALE. If the latched Chip Enables are active and IO/$\overline{M}$ is low when $\overline{RD}$ goes low, the contents of the ROM location addressed by the latched address are put out through AD_{0-7} output buffers.

I/O Section

The I/O section of the chip is addressed by the latched value of AD_{0-1}. Two 8-bit Data Direction Registers (DDR) in 8355 determine the input/output status of each pin in the corresponding ports. A "0" in a particular bit position of a DDR signifies that the corresponding I/O port bit is in the input mode. A "1" in a particular bit position signifies that the corresponding I/O port bit is in the output mode. In this manner the I/O ports of the 8355 are bit-by-bit programmable as inputs or outputs. The table summarizes port and DDR designation. DDR's cannot be read.

AD_1	AD_0	Selection
0	0	Port A
0	1	Port B
1	0	Port A Data Direction Register (DDR A)
1	1	Port B Data Direction Register (DDR B)

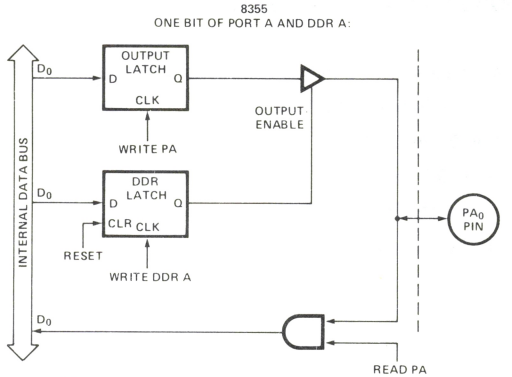
When $\overline{IOW}$ goes low and the Chip Enables are active, the data on the AD_{0-7} is written into I/O port selected by the latched value of AD_{0-1}. During this operation all I/O bits of the selected port are affected, regardless of their I/O mode and the state of IO/$\overline{M}$. The actual output level does not change until $\overline{IOW}$ returns high (glitch free output).

A port can be read out when the latched Chip Enables are active and either $\overline{RD}$ goes low with IO/$\overline{M}$ high, or $\overline{IOR}$ goes low. Both input and output mode bits of a selected port will appear on lines AD_{0-7}.

To clarify the function of the I/O ports and Data Direction Registers, the following diagram shows the configuration of one bit of PORT A and DDR A. The same logic applies to PORT B and DDR B.

Note that hardware RESET or writing a zero to the DDR latch will cause the output latch's output buffer to be disabled, preventing the data in the output latch from being passed through to the pin. This is equivalent to putting the port in the input mode. Note also that the data can be written to the Output Latch even though the Output Buffer has been disabled. This enables a port to be initialized with a value prior to enabling the output.

The diagram also shows that the contents of PORT A and PORT B can be read even when the ports are configured as outputs.



WRITE PA = ($\overline{IOW}$=0) • (CHIP ENABLES ACTIVE) • (PORT A ADDRESS SELECTED)
WRITE DDR A = ($\overline{IOW}$=0) • (CHIP ENABLES ACTIVE) • (DDR A ADDRESS SELECTED)
READ PA = $\{[(IO/\overline{M}=1) \bullet (\overline{RD}=0)] + (\overline{IOR}=0)\}$ • (CHIP ENABLES ACTIVE) • (PORT A ADDRESS SELECTED)

NOTE: WRITE PA IS NOT QUALIFIED BY IO/$\overline{M}$.

System Interface with 8085A and 8088

A system using the 8355 can use either one of the two I/O Interface techniques:

- Standard I/O
- Memory Mapped I/O

If a standard I/O technique is used, the system can use the feature of both CE and $\overline{CE}$. By using a combination of unused address lines A_{11-15} and the Chip Enable inputs, the system can use up to 5 each 8355's without requiring a CE decoder. See Figure 2a and 2b.

If a memory mapped I/O approach is used the 8355 will be selected by the combination of both the Chip Enables and IO/$\overline{M}$ using the AD_{8-15} address lines. See Figure 1.

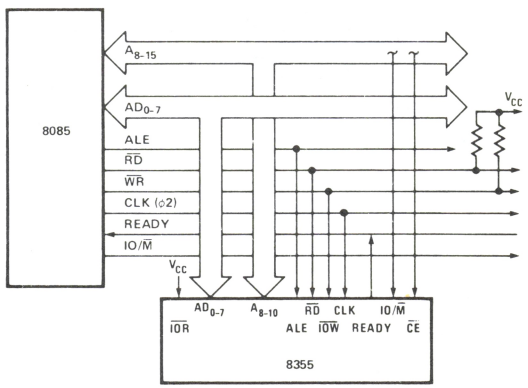


Figure 1. 8355 in 8085A System (Memory-Mapped I/O)

8088 FIVE CHIP SYSTEM

Figure 2a shows a five chip system containing:

- 1.25 K Bytes RAM
- 2 K Bytes ROM
- 38 I/O Pins
- 1 Internal Timer
- 2 Interrupt Levels

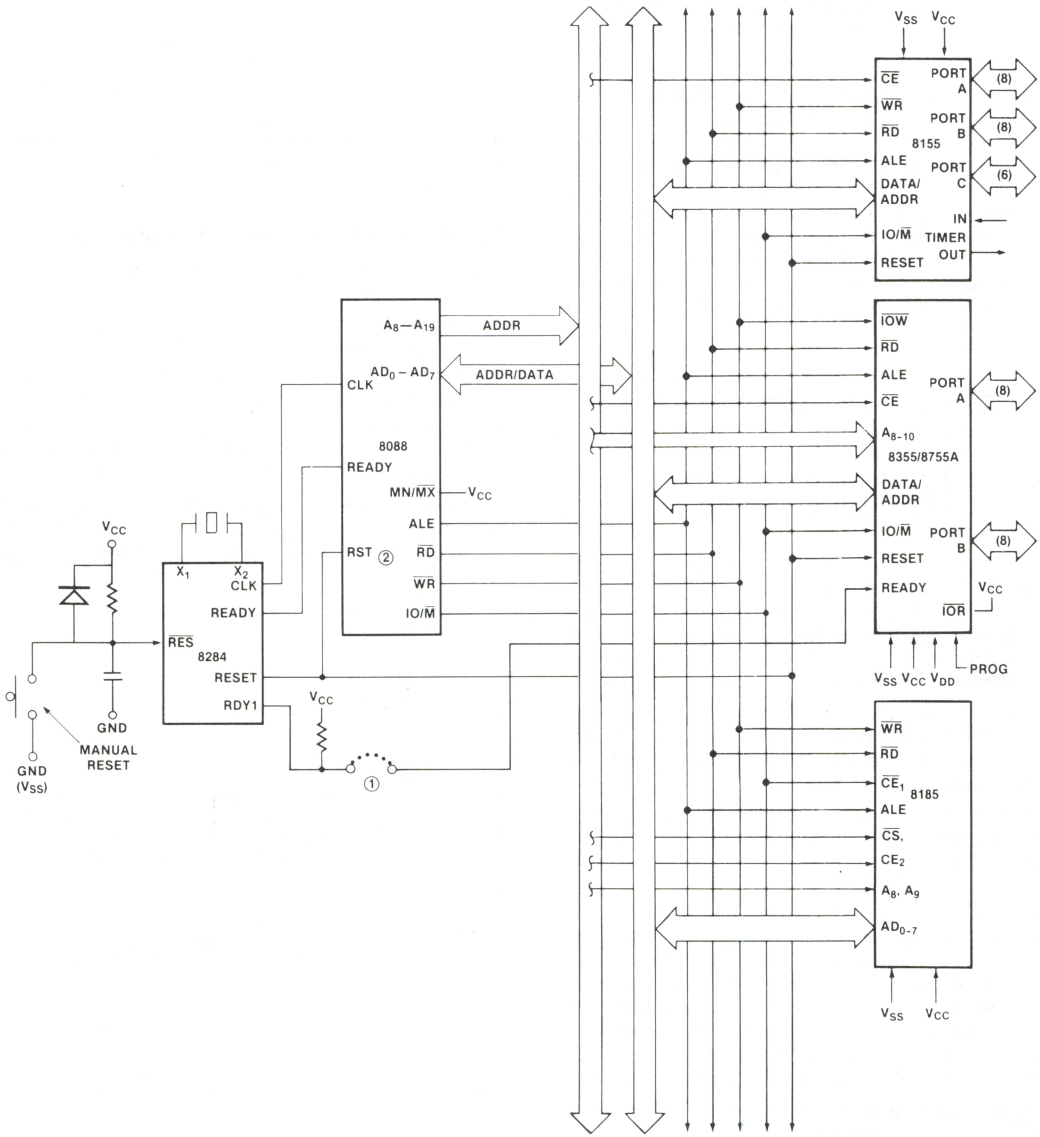
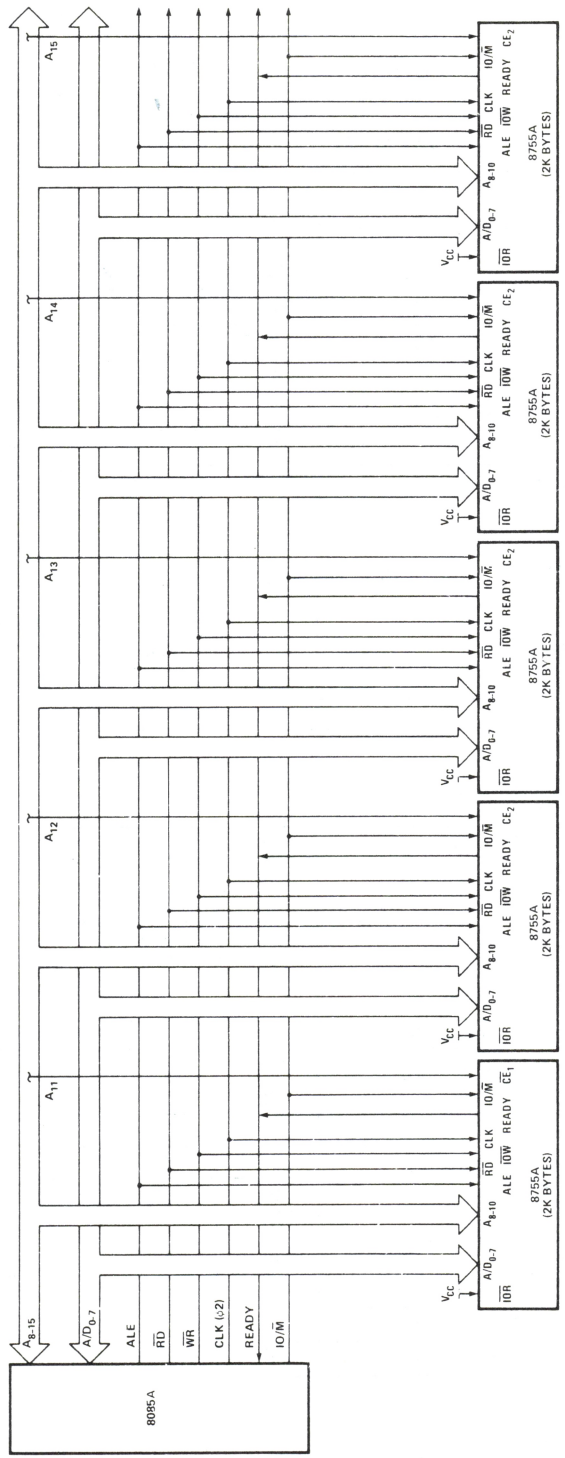


Figure 2a. 8088 Five Chip System Configuration



Note: Use $\overline{CE}_1$ for the first 8755A in the system, and CE_2 for the other 8755A's. Permits up to 5-8755A's in a system without CE decoder.

Figure 2b. 8355 in 8085A System (Standard I/O)

ABSOLUTE MAXIMUM RATINGS*

Temperature Under Bias ..... 0°C to +70°C
Storage Temperature ..... -65°C to +150°C
Voltage on Any Pin
With Respect to Ground ..... -0.5V to +7V
Power Dissipation 1.5W

COMMENT: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

D.C. CHARACTERISTICS (T_A = 0°C to 70°C; V_{CC} = 5V ± 5%)

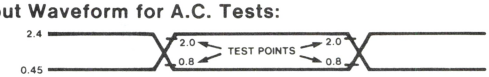
SYMBOL	PARAMETER	MIN.	MAX.	UNITS	TEST CONDITIONS
V_{IL}	Input Low Voltage	-0.5	0.8	V	V_{CC} = 5.0V
V_{IH}	Input High Voltage	2.0	V_{CC}+0.5	V	V_{CC} = 5.0V
V_{OL}	Output Low Voltage		0.45	V	I_{OL} = 2mA
V_{OH}	Output High Voltage	2.4		V	I_{OH} = -400μA
I_{IL}	Input Leakage		10	μA	V_{IN} = V_{CC} to 0V
I_{LO}	Output Leakage Current		±10	μA	0.45V ≤V_{OUT} ≤V_{CC}
I_{CC}	V_{CC} Supply Current		180	mA	

A.C. CHARACTERISTICS (T_A = 0°C to 70°C; V_{CC} = 5V ± 5%)

		8355		8355-2 (Preliminary)		
Symbol	Parameter	Min.	Max.	Min.	Max.	Units
t_{CYC}	Clock Cycle Time	320		200		ns
T_1	CLK Pulse Width	80		40		ns
T_2	CLK Pulse Width	120		70		ns
t_f,t_r	CLK Rise and Fall Time		30		30	ns
t_{AL}	Address to Latch Set Up Time	50		30		ns
t_{LA}	Address Hold Time after Latch	80		30		ns
t_{LC}	Latch to READ/WRITE Control	100		40		ns
t_{RD}	Valid Data Out Delay from READ Control		170		140	ns
t_{AD}	Address Stable to Data Out Valid		400		330	ns
t_{LL}	Latch Enable Width	100		70		ns
t_{RDF}	Data Bus Float after READ	0	100	0	85	ns
t_{CL}	READ/WRITE Control to Latch Enable	20		10		ns
t_{CC}	READ/WRITE Control Width	250		200		ns
t_{DW}	Data In to Write Set Up Time	150		150		ns
t_{WD}	Data In Hold Time After WRITE	10		10		ns
t_{WP}	WRITE to Port Output		400		400	ns
t_{PR}	Port Input Set Up Time	50		50		ns
t_{RP}	Port Input Hold Time	50		50		ns
t_{RYH}	READY HOLD Time	0	160	0	160	ns
t_{ARY}	ADDRESS (CE) to READY		160		160	ns
t_{RV}	Recovery Time Between Controls	300		200		ns
t_{RDE}	READ Control to Data Bus Enable	10		10		ns

Note: C_{LOAD} = 150pF

Input Waveform for A.C. Tests:



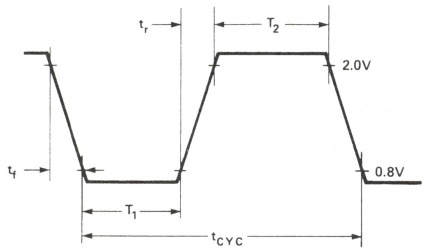


Figure 3. Clock Specification for 8355

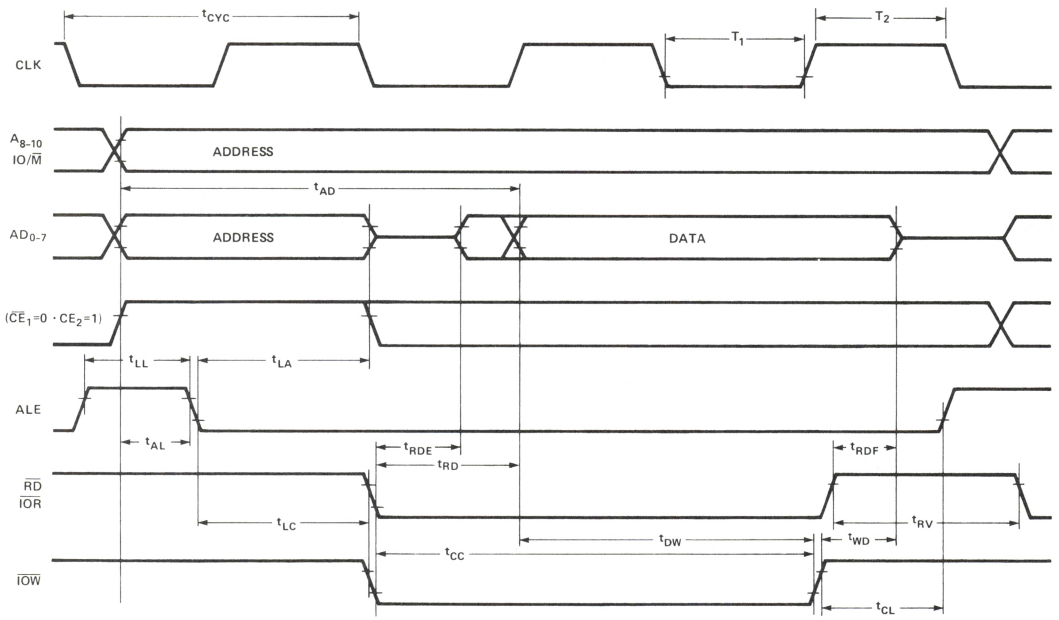
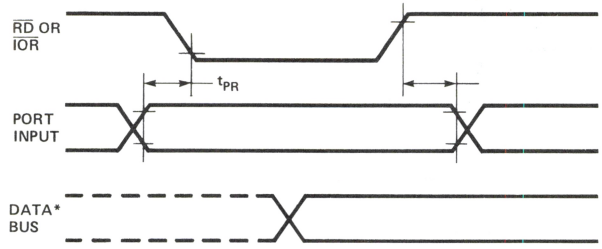
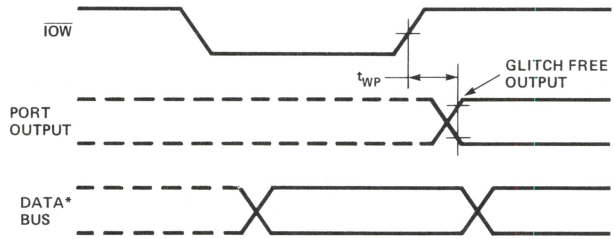


Figure 4. ROM Read and I/O Read and Write

a. Input Mode



b. Output Mode



*DATA BUS TIMING IS SHOWN IN FIGURE 4.

Figure 5. I/O Port Timing

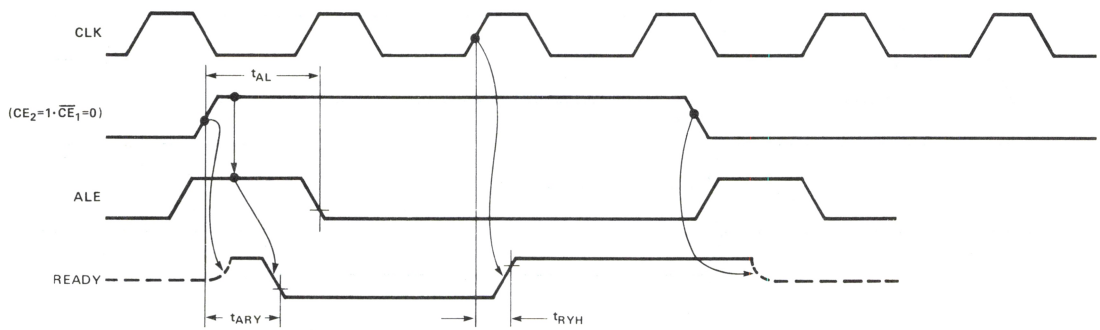


Figure 6. Wait State Timing (Ready = 0)

8755A/8755A-2
16,384-BIT EPROM WITH I/O

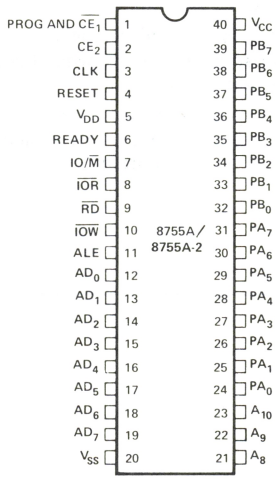
- 2048 Words x 8 Bits
- Single +5V Power Supply (V_{CC})
- Directly Compatible with 8085A and 8088 Microprocessors
- U.V. Erasable and Electrically Reprogrammable
- Internal Address Latch
- 2 General Purpose 8-Bit I/O Ports
- Each I/O Port Line Individually Programmable as Input or Output
- Multiplexed Address and Data Bus
- 40-Pin DIP

The Intel® 8755A is an erasable and electrically reprogrammable ROM (EPROM) and I/O chip to be used in the 8085A and 8088 microprocessor systems. The EPROM portion is organized as 2048 words by 8 bits. It has a maximum access time of 450 ns to permit use with no wait states in an 8085A CPU.

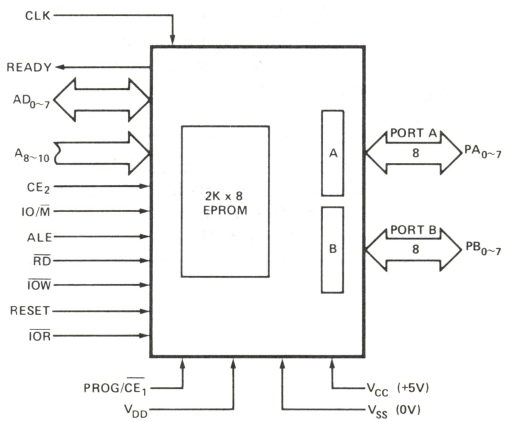
The I/O portion consists of 2 general purpose I/O ports. Each I/O port has 8 port lines, and each I/O port line is individually programmable as input or output.

The 8755A-2 is a high speed selected version of the 8755A compatible with the 5 MHz 8085A-2 and the full speed 5 MHz 8088.

PIN CONFIGURATION



BLOCK DIAGRAM



8755A FUNCTIONAL PIN DEFINITION

Symbol	Function
ALE (input)	When Address Latch Enable goes high, AD_{0-7}, IO/M, A_{8-10}, CE_2, and $\overline{CE_1}$ enter the address latches. The signals (AD, IO/M, A_{8-10}, CE) are latched in at the trailing edge of ALE.
AD_{0-7} (input/output)	Bidirectional Address/Data bus. The lower 8-bits of the PROM or I/O address are applied to the bus lines when ALE is high. During an I/O cycle, Port A or B are selected based on the latched value of AD_0. If $\overline{RD}$ or $\overline{IOR}$ is low when the latched Chip Enables are active, the output buffers present data on the bus.
A_{8-10} (input)	These are the high order bits of the PROM address. They do not affect I/O operations.
PROG/$\overline{CE_1}$ CE_2 (input)	Chip Enable Inputs: $\overline{CE_1}$ is active low and CE_2 is active high. The 8755A can be accessed only when *BOTH* Chip Enables are active at the time the ALE signal latches them up. If either Chip Enable input is not active, the AD_{0-7} and READY outputs will be in a high impedance state. $\overline{CE_1}$ is also used as a programming pin. (See section on programming.)
IO/$\overline{M}$ (input)	If the latched IO/$\overline{M}$ is high when $\overline{RD}$ is low, the output data comes from an I/O port. If it is low the output data comes from the PROM.
$\overline{RD}$ (input)	If the latched Chip Enables are active when $\overline{RD}$ goes low, the AD_{0-7} output buffers are enabled and output either the selected PROM location or I/O port. When both $\overline{RD}$ and $\overline{IOR}$ are high, the AD_{0-7} output buffers are 3-stated.
$\overline{IOW}$ (input)	If the latched Chip Enables are active, a low on $\overline{IOW}$ causes the output port pointed to by the latched value of AD_0 to be written with the data on AD_{0-7}. The state of IO/$\overline{M}$ is ignored.
CLK (input)	The CLK is used to force the READY into its high impedance state after it has been forced low by $\overline{CE_1}$ low, CE_2 high, and ALE high.
READY (output)	READY is a 3-state output controlled by CE_2, $\overline{CE_1}$, ALE and CLK. READY is forced low when the Chip Enables are active during the time ALE is high, and remains low until the rising edge of the next CLK. (See Figure 6.)
PA_{0-7} (input/output)	These are general purpose I/O pins. Their input/output direction is determined by the contents of Data Direction Register (DDR). Port A is selected for write operations when the Chip Enables are active and $\overline{IOW}$ is low and a 0 was previously latched from AD_0, AD_1. Read operation is selected by either $\overline{IOR}$ low and active Chip Enables and AD_0 and AD_1 low, *or* IO/$\overline{M}$ high, $\overline{RD}$ low, active Chip Enables, and AD_0 and AD_1 low.
PB_{0-7} (input/output)	This general purpose I/O port is identical to Port A except that it is selected by a 1 latched from AD_0 and a 0 from AD_1.
RESET (input)	In normal operation, an input high on RESET causes all pins in Ports A and B to assume input mode (clear DDR register).
$\overline{IOR}$ (input)	When the Chip Enables are active, a low on $\overline{IOR}$ will output the selected I/O port onto the AD bus. $\overline{IOR}$ low performs the same function as the combination of IO/$\overline{M}$ high and $\overline{RD}$ low. When $\overline{IOR}$ is not used in a system, $\overline{IOR}$ should be tied to V_{CC} ("1").
V_{CC}	+5 volt supply.
V_{SS}	Ground Reference.
V_{DD}	V_{DD} is a programming voltage, and must be tied to +5V when the 8755A is being read. For programming, a high voltage is supplied with V_{DD} = 25V, typical. (See section on programming.)

FUNCTIONAL DESCRIPTION

PROM Section

The 8755A contains an 8-bit address latch which allows it to interface directly to MCS-48 and MCS-85 Microcomputers without additional hardware.

The PROM section of the chip is addressed by the 11-bit address and CE. The address, $\overline{CE}_1$ and CE_2 are latched into the address latches on the falling edge of ALE. If the latched Chip Enables are active and IO/$\overline{M}$ is low when $\overline{RD}$ goes low, the contents of the PROM location addressed by the latched address are put out on the AD_{0-7} lines.

I/O Section

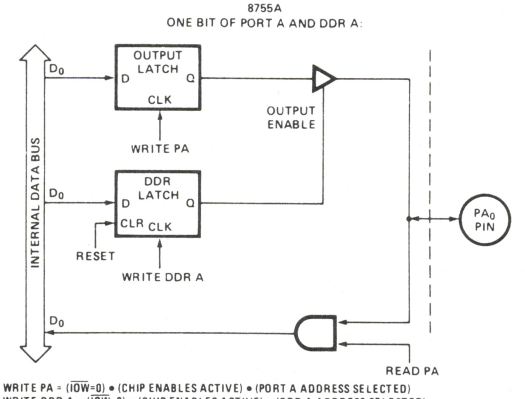
The I/O section of the chip is addressed by the latched value of AD_{0-1}. Two 8-bit Data Direction Registers (DDR) in 8755A determine the input/output status of each pin in the corresponding ports. A "0" in a particular bit position of a DDR signifies that the corresponding I/O port bit is in the input mode. A "1" in a particular bit position signifies that the corresponding I/O port bit is in the output mode. In this manner the I/O ports of the 8755A are bit-by-bit programmable as inputs or outputs. The table summarizes port and DDR designation. DDR's cannot be read.

AD_1	AD_0	Selection
0	0	Port A
0	1	Port B
1	0	Port A Data Direction Register (DDR A)
1	1	Port B Data Direction Register (DDR B)

When $\overline{IOW}$ goes low and the Chip Enables are active, the data on the AD is written into I/O port selected by the latched value of AD_{0-1}. During this operation all I/O bits of the selected port are affected, regardless of their I/O mode and the state of IO/$\overline{M}$. The actual output level does not change until $\overline{IOW}$ returns high. (glitch free output)

A port can be read out when the latched Chip Enables are active and either $\overline{RD}$ goes low with IO/$\overline{M}$ high, or $\overline{IOR}$ goes low. Both input and output mode bits of a selected port will appear on lines AD_{0-7}.

To clarify the function of the I/O Ports and Data Direction Registers, the following diagram shows the configuration of one bit of PORT A and DDR A. The same logic applies to PORT B and DDR B.



WRITE PA = ($\overline{IOW}$=0) • (CHIP ENABLES ACTIVE) • (PORT A ADDRESS SELECTED)
WRITE DDR A = ($\overline{IOW}$=0) • (CHIP ENABLES ACTIVE) • (DDR A ADDRESS SELECTED)
READ PA = $\{[(IO/\overline{M}=1) \bullet (\overline{RD}=0)] + (\overline{IOR}=0)\}$ • (CHIP ENABLES ACTIVE) • (PORT A ADDRESS SELECTED)

NOTE: WRITE PA IS NOT QUALIFIED BY IO/$\overline{M}$.

Note that hardware RESET or writing a zero to the DDR latch will cause the output latch's output buffer to be disabled, preventing the data in the Output Latch from being passed through to the pin. This is equivalent to putting the port in the input mode. Note also that the data can be written to the Output Latch even though the Output Buffer has been disabled. This enables a port to be initialized with a value prior to enabling the output.

The diagram also shows that the contents of PORT A and PORT B can be read even when the ports are configured as outputs.

TABLE 1. 8755A PROGRAMMING MODULE CROSS REFERENCE

MODULE NAME	USE WITH
UPP 955	UPP(4)
UPP UP2(2)	UPP 855
PROMPT 975	PROMPT 80/85(3)
PROMPT 475	PROMPT 48(1)

NOTES:
1. Described on p. 13-34 of 1978 Data Catalog.
2. Special adaptor socket.
3. Described on p. 13-39 of 1978 Data Catalog.
4. Described on p. 13-71 of 1978 Data Catalog.

ERASURE CHARACTERISTICS

The erasure characteristics of the 8755A are such that erasure begins to occur when exposed to light with wavelengths shorter than approximately 4000 Angstroms (Å). It should be noted that sunlight and certain types of fluorescent lamps have wavelengths in the 3000-4000Å range. Data show that constant exposure to room level fluorescent lighting could erase the typical 8755A in approximately 3 years while it would take approximately 1 week to cause erasure when exposed to direct sunlight. If the 8755A is to be exposed to these types of lighting conditions for extended periods of time, opaque labels are available from Intel which should be placed over the 8755 window to prevent unintentional erasure.

The recommended erasure procedure for the 8755A is exposure to shortwave ultraviolet light which has a wavelength of 2537 Angstroms (Å). The integrated dose (i.e., UV intensity X exposure time) for erasure should be a minimum of 15W-sec/cm^2. The erasure time with this dosage is approximately 15 to 20 minutes using an ultraviolet lamp with a 12000μW/cm^2 power rating. The 8755A should be placed within one inch from the lamp tubes during erasure. Some lamps have a filter on their tubes and this filter should be removed before erasure.

PROGRAMMING

Initially, and after each erasure, all bits of the EPROM portions of the 8755A are in the "1" state. Information is introduced by selectively programming "0" into the desired bit locations. A programmed "0" can only be changed to a "1" by UV erasure.

The 8755A can be programmed on the Intel® Universal PROM Programmer (UPP), and the PROMPT™ 80/85 and PROMPT-48™ design aids. The appropriate programming modules and adapters for use in programming both 8755A's and 8755's are shown in Table 1.

The program mode itself consists of programming a single address at a time, giving a single 50 msec pulse for every address. Generally, it is desirable to have a verify cycle after a program cycle for the same address as shown in the attached timing diagram. In the verify cycle (i.e., normal memory read cycle) 'V_{DD}' should be at +5V.

Preliminary timing diagrams and parameter values pertaining to the 8755A programming operation are contained in Figure 7.

SYSTEM APPLICATIONS

System Interface with 8085A and 8088

A system using the 8755A can use either one of the two I/O Interface techniques:

- Standard I/O
- Memory Mapped I/O

If a standard I/O technique is used, the system can use the feature of both CE_3 and $\overline{CE}_1$. By using a combination of unused address lines A_{11-15} and the Chip Enable inputs, the 8085A system can use up to 5 each 8755A's without requiring a CE decoder. See Figure 2a and 2b.

If a memory mapped I/O approach is used the 8755A will be selected by the combination of both the Chip Enables and IO/$\overline{M}$ using the AD_{8-15} address lines. See Figure 1.

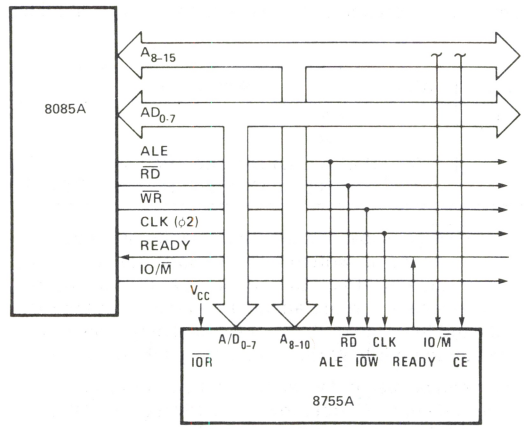


Figure 1. 8755A in 8085A System (Memory-Mapped I/O)

8088 FIVE CHIP SYSTEM

Figure 1b shows a five chip system containing:

- 1.25 K Bytes RAM
- 2 K Bytes ROM
- 38 I/O Pins
- 1 Interval Timer
- 2 Interrupt Levels

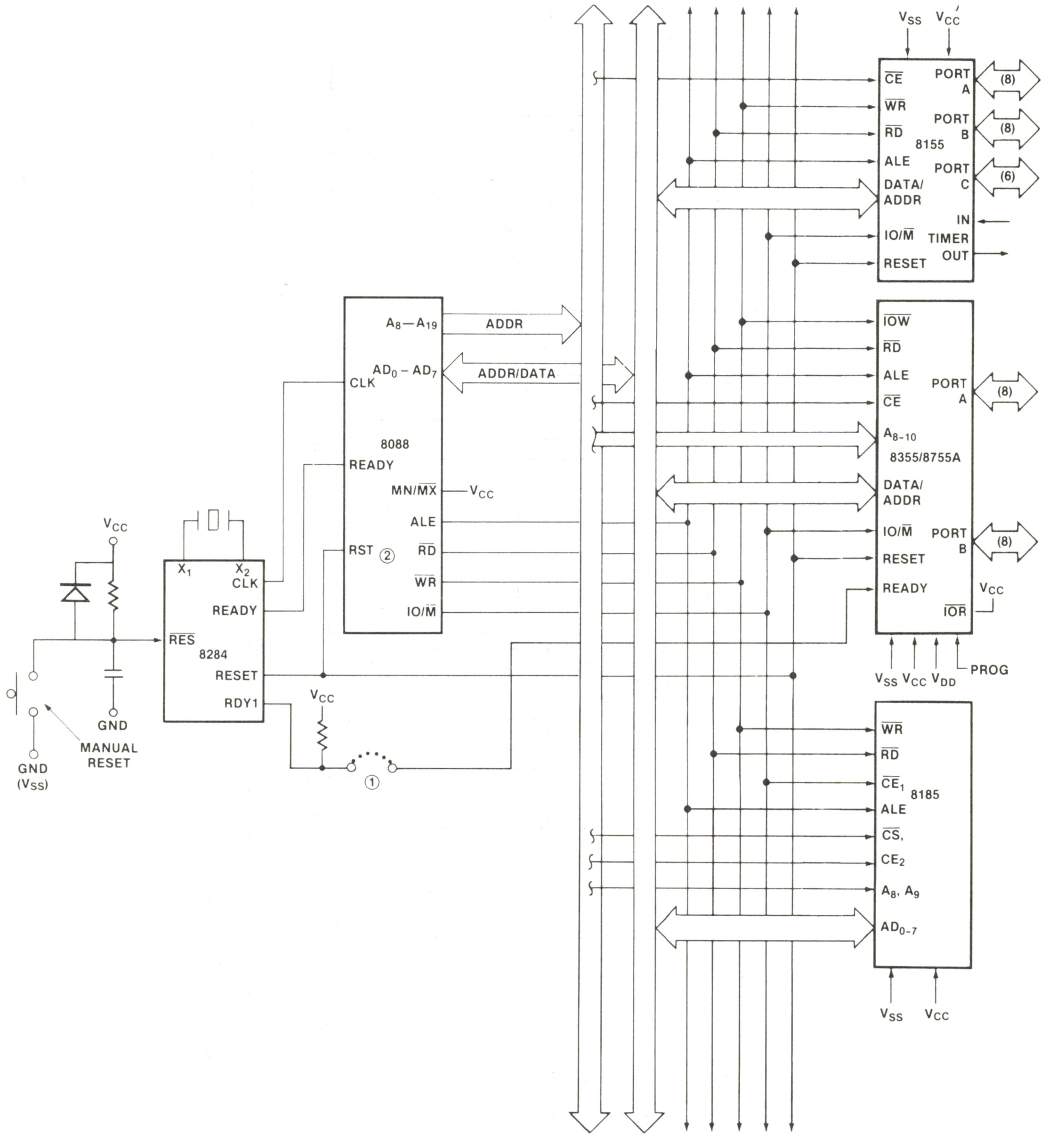
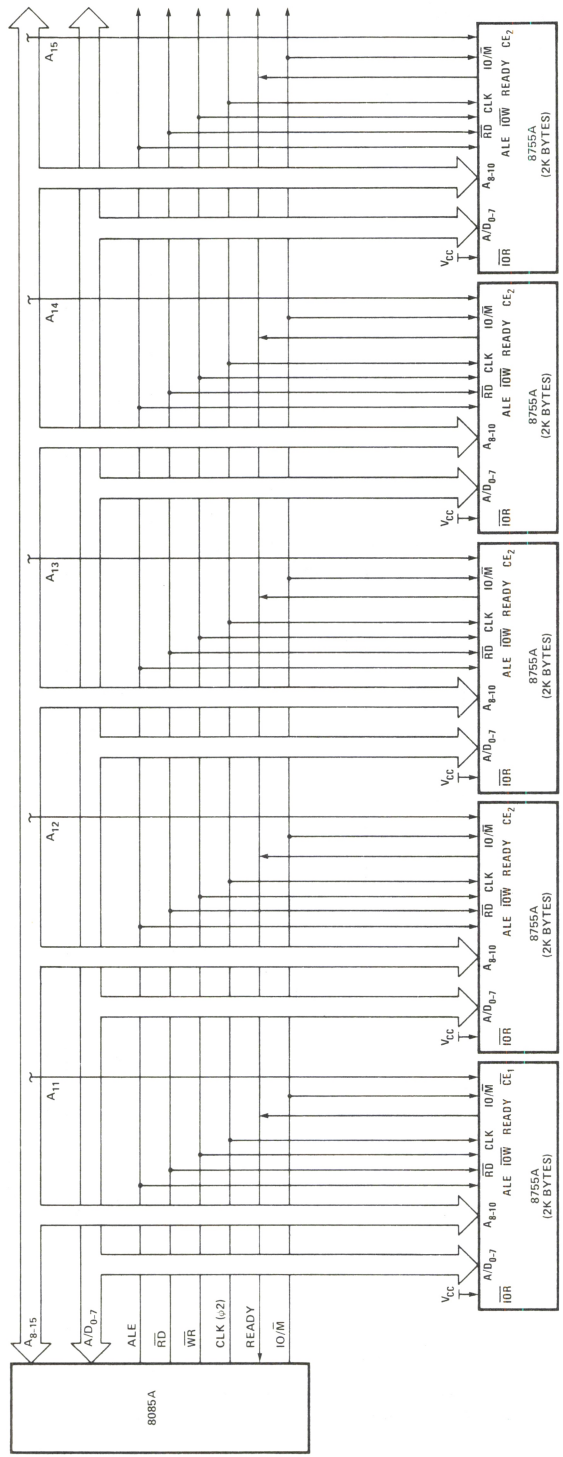


Figure 2a. 8088 Five Chip System Configuration



Note: Use $\overline{CE}_1$ for the first 8755A in the system, and CE_2 for the other 8755A's. Permits up to 5-8755A's in a system without CE decoder.

Figure 2b. 8755A in 8085A System (Standard I/O)

ABSOLUTE MAXIMUM RATINGS*

Temperature Under Bias ..... 0°C to +70°C
Storage Temperature ..... -65°C to +150°C
Voltage on Any Pin
With Respect to Ground ..... -0.5V to +7V
Power Dissipation 1.5W

COMMENT: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

D.C. CHARACTERISTICS (T_A = 0°C to 70°C; V_{CC} = 5V ± 5%)

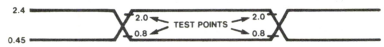
SYMBOL	PARAMETER	MIN.	MAX.	UNITS	TEST CONDITIONS
V_{IL}	Input Low Voltage	-0.5	0.8	V	V_{CC} = 5.0V
V_{IH}	Input High Voltage	2.0	V_{CC}+0.5	V	V_{CC} = 5.0V
V_{OL}	Output Low Voltage		0.45	V	I_{OL} = 2mA
V_{OH}	Output High Voltage	2.4		V	I_{OH} = -400μA
I_{IL}	Input Leakage		10	μA	V_{IN} = V_{CC} to 0V
I_{LO}	Output Leakage Current		±10	μA	0.45V ≤V_{OUT} ≤V_{CC}
I_{CC}	V_{CC} Supply Current		180	mA	

A.C. CHARACTERISTICS (T_A = 0°C to 70°C; V_{CC} = 5V ± 5%)

		8755A		8755A-2 (Preliminary)		
Symbol	Parameter	Min.	Max.	Min.	Max.	Units
t_{CYC}	Clock Cycle Time	320		200		ns
T_1	CLK Pulse Width	80		40		ns
T_2	CLK Pulse Width	120		70		ns
t_f,t_r	CLK Rise and Fall Time		30		30	ns
t_{AL}	Address to Latch Set Up Time	50		30		ns
t_{LA}	Address Hold Time after Latch	80		45		ns
t_{LC}	Latch to READ/WRITE Control	100		40		ns
t_{RD}	Valid Data Out Delay from READ Control		170		140	ns
t_{AD}	Address Stable to Data Out Valid		450		330	ns
t_{LL}	Latch Enable Width	100		70		ns
t_{RDF}	Data Bus Float after READ	0	100	0	85	ns
t_{CL}	READ/WRITE Control to Latch Enable	20		10		ns
t_{CC}	READ/WRITE Control Width	250		200		ns
t_{DW}	Data In to Write Set Up Time	150		150		ns
t_{WD}	Data In Hold Time After WRITE	30		10		ns
t_{WP}	WRITE to Port Output		400		400	ns
t_{PR}	Port Input Set Up Time	50		50		ns
t_{RP}	Port Input Hold Time	50		50		ns
t_{RYH}	READY HOLD Time	0	160	0	160	ns
t_{ARY}	ADDRESS (CE) to READY		160		160	ns
t_{RV}	Recovery Time Between Controls	300		200		ns
t_{RDE}	READ Control to Data Bus Enable	10		10		ns
t_{LD}	ALE to Data Out Valid		350		270	ns

Note: C_{LOAD} = 150pF

Input Waveform for A.C. Tests:



WAVEFORMS

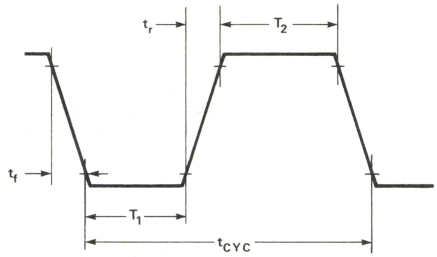


Figure 3. Clock Specification for 8755A

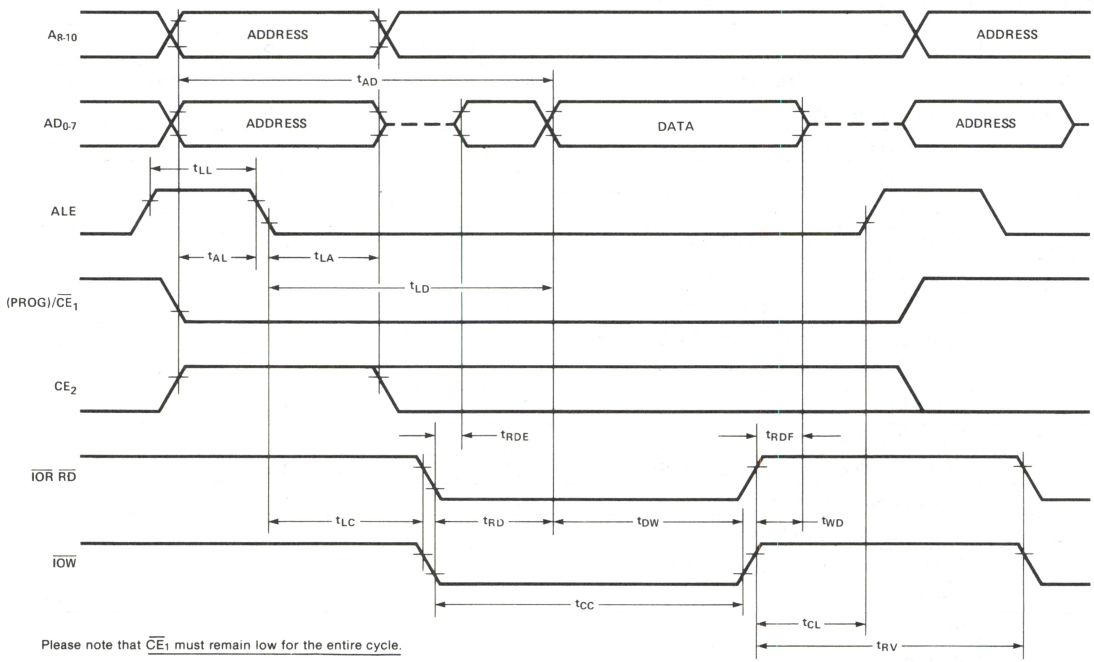


Figure 4. PROM Read, I/O Read and Write Timing

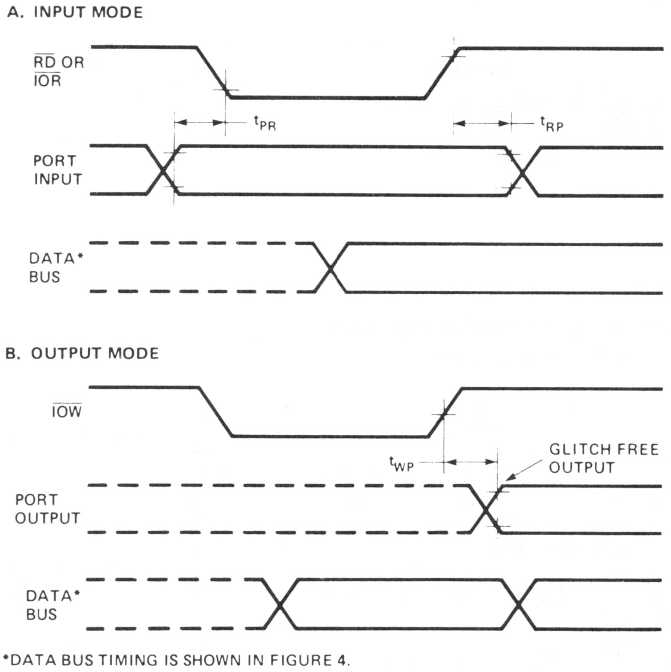


Figure 5. I/O Port Timing

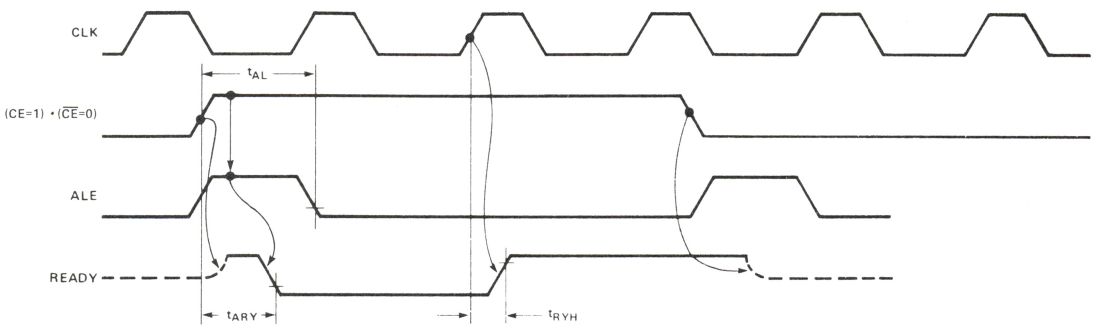


Figure 6. Wait State Timing (READY = 0)

D.C. SPECIFICATION PROGRAMMING

(T_A = 0°C to 70°C; V_{CC} = 5V ± 5%; V_{SS} = 0V)

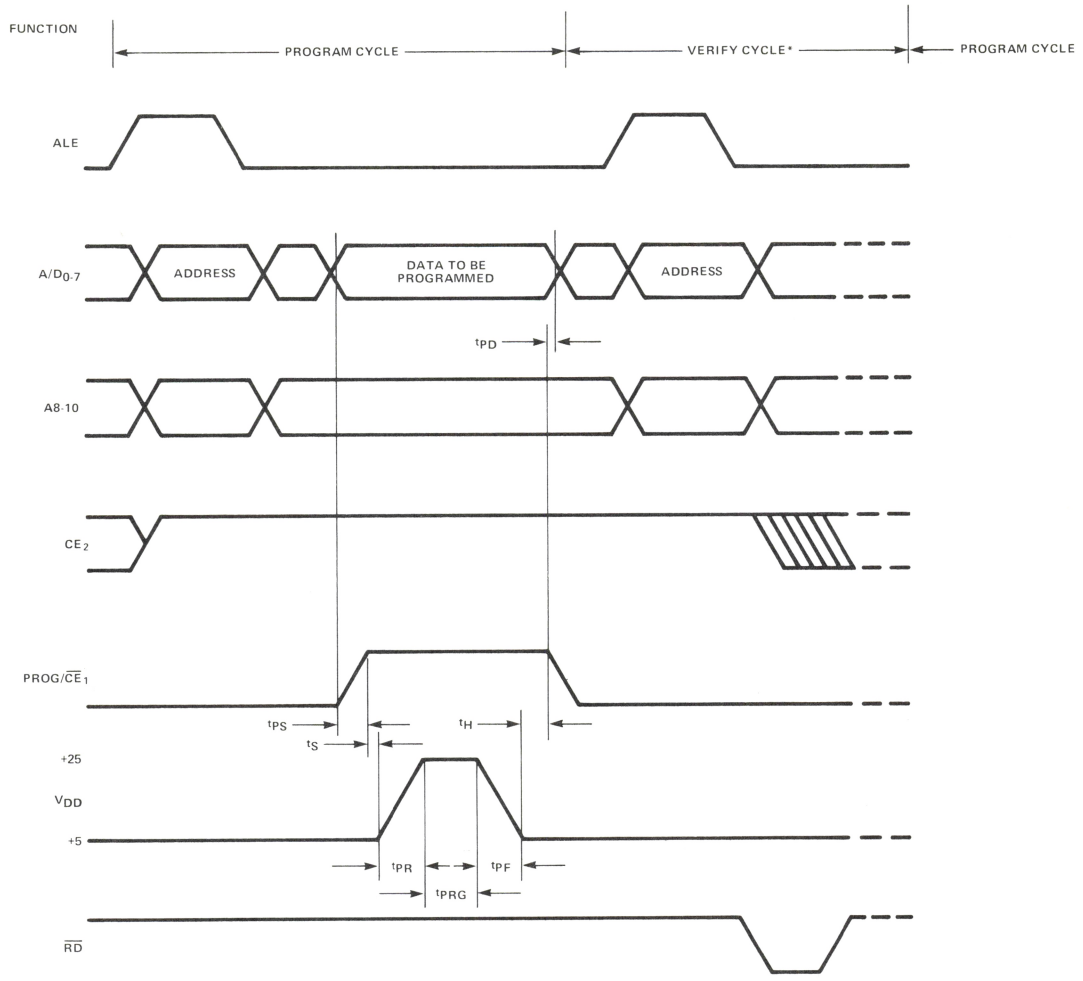
Symbol	Parameter	Min.	Typ.	Max.	Unit
V_{DD}	Programming Voltage (during Write to EPROM)	24	25	26	V
I_{DD}	Prog Supply Current		15	30	mA

A.C. SPECIFICATION FOR PROGRAMMING

(T_A = 0°C to 70°C; V_{CC} = 5V ± 5%; V_{SS} = 0V)

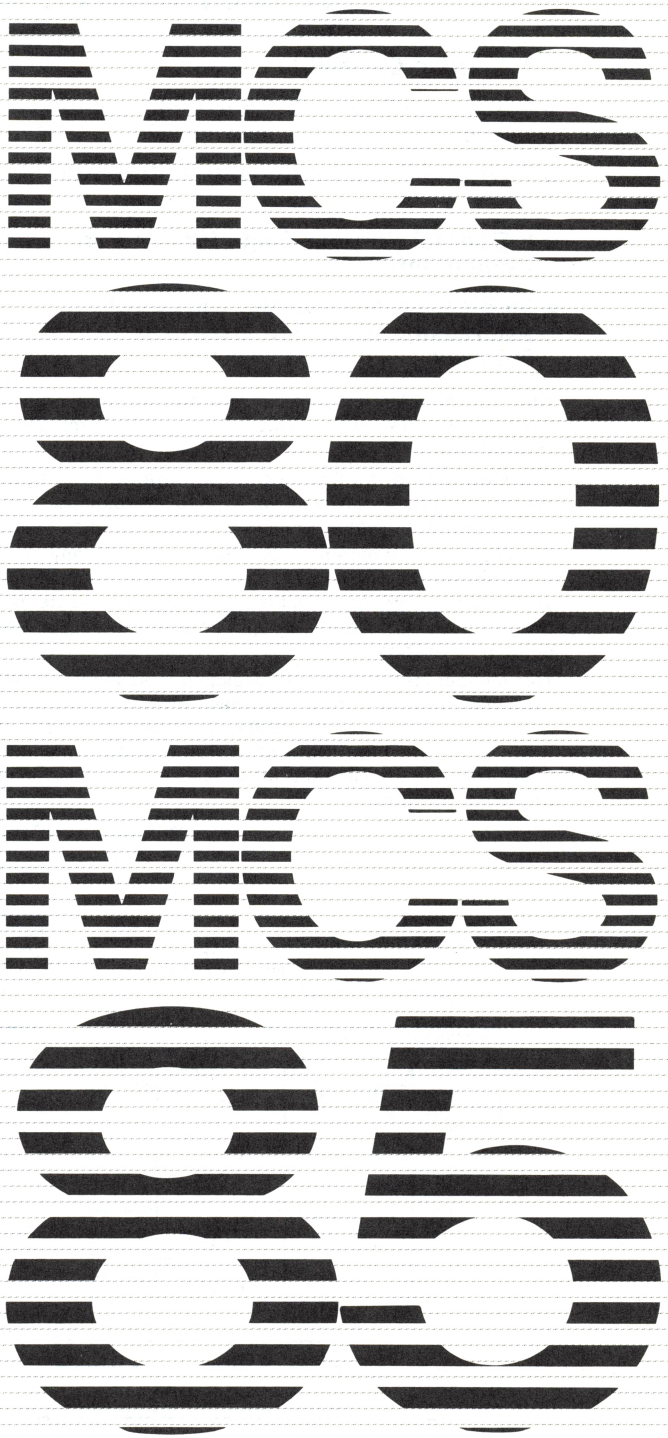
Symbol	Parameter	Min.	Typ.	Max.	Unit
t_{PS}	Data Setup Time	10			ns
t_{PD}	Data Hold Time	0			ns
t_S	Prog Pulse Setup Time	2			μs
t_H	Prog Pulse Hold Time	2			μs
t_{PR}	Prog Pulse Rise Time	0.01	2		μs
t_{PF}	Prog Pulse Fall Time	0.01	2		μs
t_{PRG}	Prog Pulse Width	45	50		msec

WAVEFORMS



*VERIFY CYCLE IS A REGULAR MEMORY READ CYCLE (WITH V_{DD} = +5V FOR 8755A)

Figure 7. 8755A Program Mode Timing Diagram



Chapter 6

MCS-85™
MCS-80™

Systems
Support
Components

Peripherals

Static RAMs

ROMs-EPROMs

8080A/8080A-1/8080A-2
8-BIT N-CHANNEL MICROPROCESSOR

The 8080A is functionally and electrically compatible with the Intel® 8080.

- **TTL Drive Capability**
- **2 μs (– 1:1.3 μs, – 2:1.5 μs) Instruction Cycle**
- **Powerful Problem Solving Instruction Set**
- **6 General Purpose Registers and an Accumulator**
- **16-Bit Program Counter for Directly Addressing up to 64K Bytes of Memory**
- **16-Bit Stack Pointer and Stack Manipulation Instructions for Rapid Switching of the Program Environment**
- **Decimal, Binary, and Double Precision Arithmetic**
- **Ability to Provide Priority Vectored Interrupts**
- **512 Directly Addressed I/O Ports**

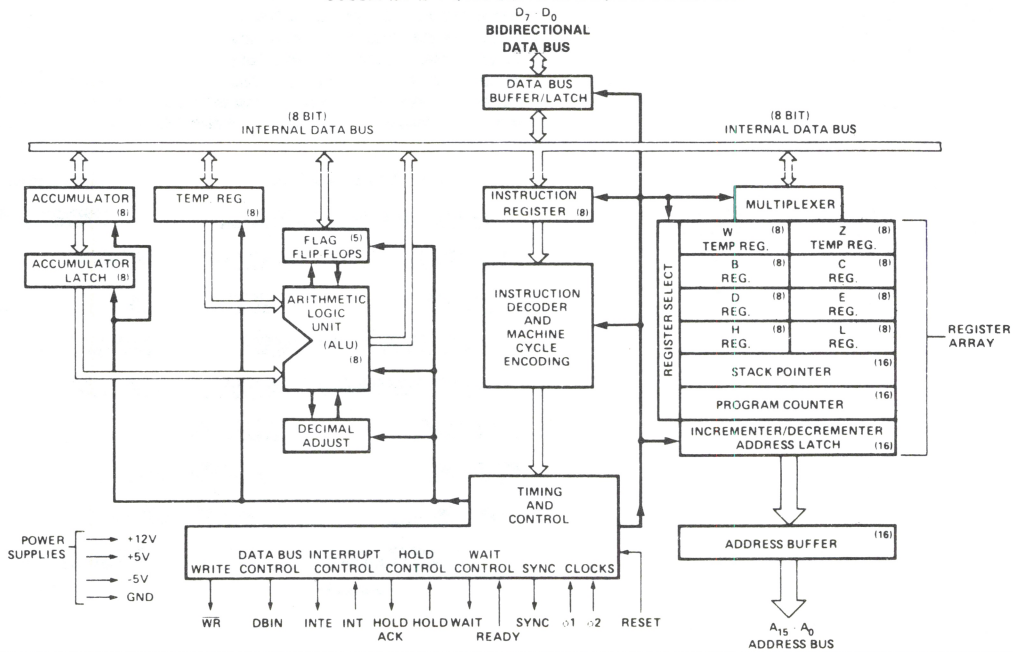
The Intel® 8080A is a complete 8-bit parallel central processing unit (CPU). It is fabricated on a single LSI chip using Intel's n-channel silicon gate MOS process. This offers the user a high performance solution to control and processing applications.

The 8080A contains 6 8-bit general purpose working registers and an accumulator. The 6 general purpose registers may be addressed individually or in pairs providing both single and double precision operators. Arithmetic and logical instructions set or reset 4 testable flags. A fifth flag provides decimal arithmetic operation.

The 8080A has an external stack feature wherein any portion of memory may be used as a last in/first out stack to store/retrieve the contents of the accumulator, flags, program counter, and all of the 6 general purpose registers. The 16-bit stack pointer controls the addressing of this external stack. This stack gives the 8080A the ability to easily handle multiple level priority interrupts by rapidly storing and restoring processor status. It also provides almost unlimited subroutine nesting.

This microprocessor has been designed to simplify systems design. Separate 16-line address and 8-line bidirectional data busses are used to facilitate easy interface to memory and I/O. Signals to control the interface to memory and I/O are provided directly by the 8080A. Ultimate control of the address and data busses resides with the HOLD signal. It provides the ability to suspend processor operation and force the address and data busses into a high impedance state. This permits OR-tying these busses with other controlling devices for (DMA) direct memory access or multiprocessor operation.

8080A CPU FUNCTIONAL BLOCK DIAGRAM



PIN DESCRIPTION

The following describes the function of all of the 8080A I/O pins. Several of the descriptions refer to internal timing periods.

A_{15}-A_0 (output three-state)
ADDRESS BUS; the address bus provides the address to memory (up to 64K 8-bit words) or denotes the I/O device number for up to 256 input and 256 output devices. A_0 is the least significant address bit.

D_7-D_0 (input/output three-state)
DATA BUS; the data bus provides bi-directional communication between the CPU, memory, and I/O devices for instructions and data transfers. Also, during the first clock cycle of each machine cycle, the 8080A outputs a status word on the data bus that describes the current machine cycle. D_0 is the least significant bit.

SYNC (output)
SYNCHRONIZING SIGNAL; the SYNC pin provides a signal to indicate the beginning of each machine cycle.

DBIN (output)
DATA BUS IN; the DBIN signal indicates to external circuits that the data bus is in the input mode. This signal should be used to enable the gating of data onto the 8080A data bus from memory or I/O.

READY (input)
READY; the READY signal indicates to the 8080A that valid memory or input data is available on the 8080A data bus. This signal is used to synchronize the CPU with slower memory or I/O devices. If after sending an address out the 8080A does not receive a READY input, the 8080A will enter a WAIT state for as long as the READY line is low. READY can also be used to single step the CPU.

WAIT (output)
WAIT; the WAIT signal acknowledges that the CPU is in a WAIT state.

$\overline{WR}$ (output)
WRITE; the $\overline{WR}$ signal is used for memory WRITE or I/O output control. The data on the data bus is stable while the $\overline{WR}$ signal is active low ($\overline{WR}$ = 0).

HOLD (input)
HOLD; the HOLD signal requests the CPU to enter the HOLD state. The HOLD state allows an external device to gain control of the 8080A address and data bus as soon as the 8080A has completed its use of these buses for the current machine cycle. It is recognized under the following conditions:

- the CPU is in the HALT state.
- the CPU is in the T2 or TW state and the READY signal is active.

As a result of entering the HOLD state the CPU ADDRESS BUS (A_{15}-A_0) and DATA BUS (D_7-D_0) will be in their high impedance state. The CPU acknowledges its state with the HOLD ACKNOWLEDGE (HLDA) pin.

HLDA (output)
HOLD ACKNOWLEDGE; the HLDA signal appears in response to the HOLD signal and indicates that the data and address bus will go to the high impedance state. The HLDA signal begins at:

- T3 for READ memory or input.
- The Clock Period following T3 for WRITE memory or OUTPUT operation.

In either case, the HLDA signal appears after the rising edge of ϕ_1 and high impedance occurs after the rising edge of ϕ_2.

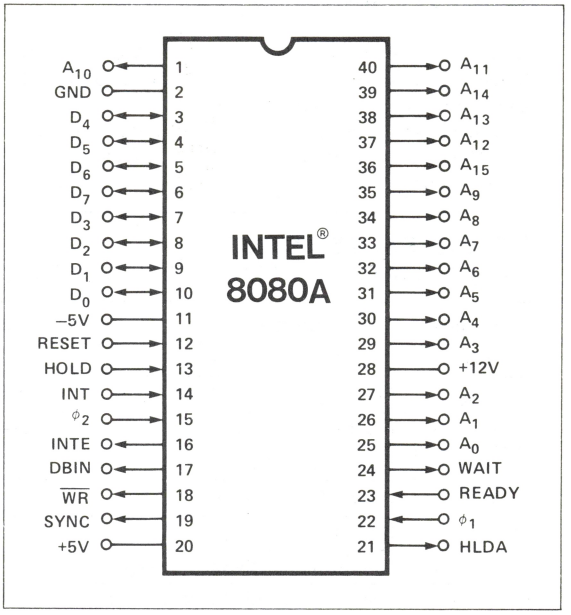


Figure 1. Pin Configuration

INTE (output)
INTERRUPT ENABLE; indicates the content of the internal interrupt enable flip/flop. This flip/flop may be set or reset by the Enable and Disable Interrupt instructions and inhibits interrupts from being accepted by the CPU when it is reset. It is automatically reset (disabling further interrupts) at time T1 of the instruction fetch cycle (M1) when an interrupt is accepted and is also reset by the RESET signal.

INT (input)
INTERRUPT REQUEST; the CPU recognizes an interrupt request on this line at the end of the current instruction or while halted. If the CPU is in the HOLD state or if the Interrupt Enable flip/flop is reset it will not honor the request.

RESET (input) [1]
RESET; while the RESET signal is activated, the content of the program counter is cleared. After RESET, the program will start at location 0 in memory. The INTE and HLDA flip/flops are also reset. Note that the flags, accumulator, stack pointer, and registers are not cleared.

V_{SS}	Ground Reference.
V_{DD}	+12 ± 5% Volts.
V_{CC}	+5 ± 5% Volts.
V_{BB}	-5 ±5% Volts (substrate bias).
ϕ_1, ϕ_2	2 externally supplied clock phases. (non TTL compatible)

ABSOLUTE MAXIMUM RATINGS*

Temperature Under Bias	0°C to +70° C
Storage Temperature	-65°C to +150°C
All Input or Output Voltages With Respect to V_{BB}	-0.3V to +20V
V_{CC}, V_{DD} and V_{SS} With Respect to V_{BB}	-0.3V to +20V
Power Dissipation	1.5W

**COMMENT: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

D.C. CHARACTERISTICS

T_A = 0°C to 70°C, V_{DD} = +12V ± 5%, V_{CC} = +5V ± 5%, V_{BB} = -5V ± 5%, V_{SS} = 0V, Unless Otherwise Noted.

Symbol	Parameter	Min.	Typ.	Max.	Unit	Test Condition
V_{ILC}	Clock Input Low Voltage	V_{SS}-1		V_{SS}+0.8	V	
V_{IHC}	Clock Input High Voltage	9.0		V_{DD}+1	V	
V_{IL}	Input Low Voltage	V_{SS}-1		V_{SS}+0.8	V	
V_{IH}	Input High Voltage	3.3		V_{CC}+1	V	
V_{OL}	Output Low Voltage			0.45	V	I_{OL} = 1.9mA on all outputs,
V_{OH}	Output High Voltage	3.7			V	I_{OH} = -150μA.
$I_{DD\,(AV)}$	Avg. Power Supply Current (V_{DD})		40	70	mA	Operation
$I_{CC\,(AV)}$	Avg. Power Supply Current (V_{CC})		60	80	mA	T_{CY} = .48 μsec
$I_{BB\,(AV)}$	Avg. Power Supply Current (V_{BB})		.01	1	mA	
I_{IL}	Input Leakage			±10	μA	$V_{SS} \leqslant V_{IN} \leqslant V_{CC}$
I_{CL}	Clock Leakage			±10	μA	$V_{SS} \leqslant V_{CLOCK} \leqslant V_{DD}$
I_{DL} [2]	Data Bus Leakage in Input Mode			-100 -2.0	μA mA	$V_{SS} \leqslant V_{IN} \leqslant V_{SS}$ +0.8V V_{SS} +0.8V $\leqslant V_{IN} \leqslant V_{CC}$
I_{FL}	Address and Data Bus Leakage During HOLD			+10 -100	μA	$V_{ADDR/DATA} = V_{CC}$ $V_{ADDR/DATA} = V_{SS}$ + 0.45V

CAPACITANCE

T_A = 25°C $V_{CC} = V_{DD} = V_{SS}$ = 0V, V_{BB} = -5V

Symbol	Parameter	Typ.	Max.	Unit	Test Condition
C_ϕ	Clock Capacitance	17	25	pf	f_c = 1 MHz
C_{IN}	Input Capacitance	6	10	pf	Unmeasured Pins
C_{OUT}	Output Capacitance	10	20	pf	Returned to V_{SS}

NOTES:

1. The RESET signal must be active for a minimum of 3 clock cycles.
2. When DBIN is high and $V_{IN} > V_{IH}$ an internal active pull up will be switched onto the Data Bus.
3. ΔI supply / ΔT_A = -0.45%/°C.

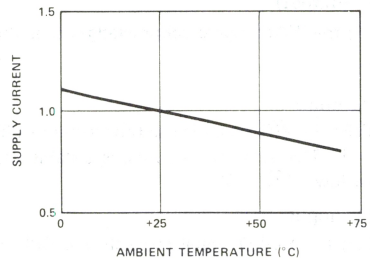


Figure 2. Typical Supply Current vs. Temperature, Normalized[3]

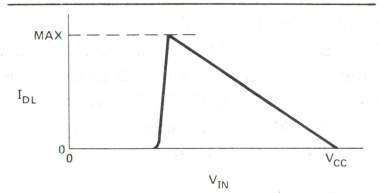


Figure 3. Data Bus Characteristic During DBIN

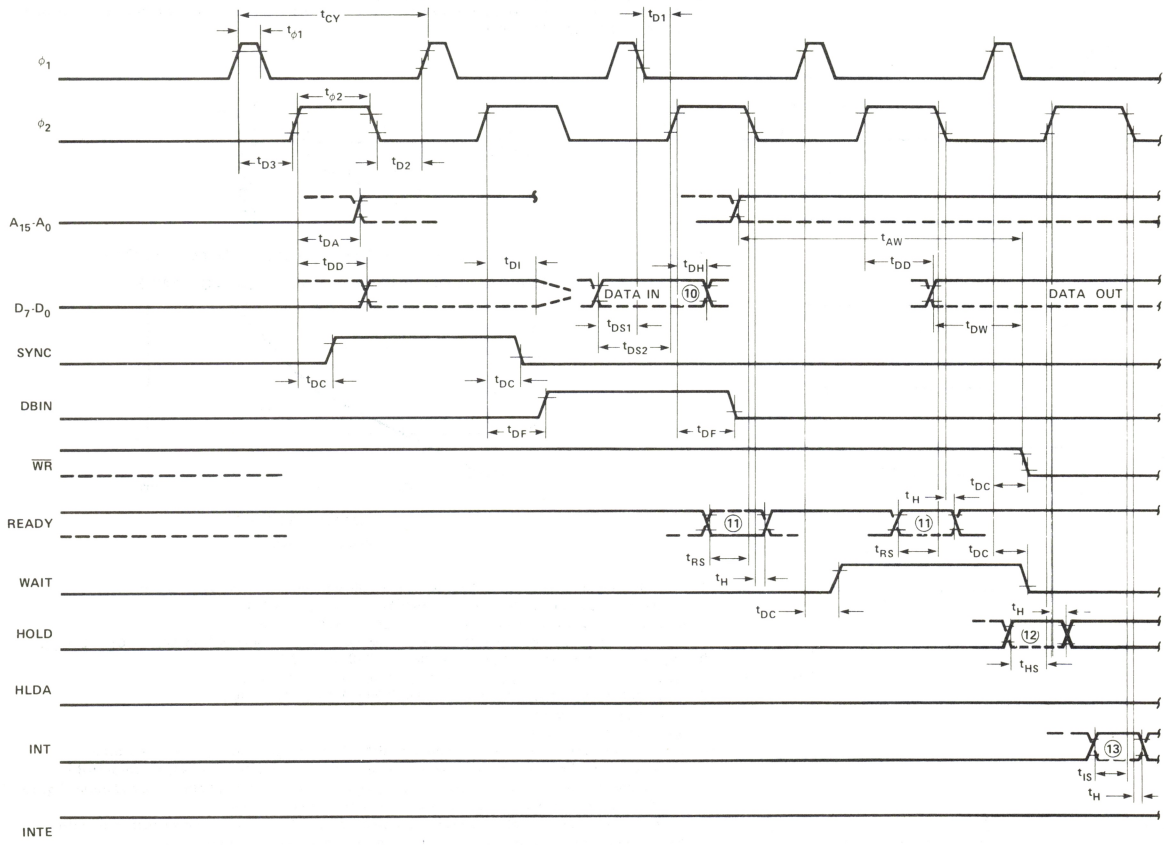
A.C. CHARACTERISTICS (8080A)

T_A = 0°C to 70°C, V_{DD} = +12V ± 5%, V_{CC} = +5V ± 5%, V_{BB} = -5V ± 5%, V_{SS} = 0V, Unless Otherwise Noted

Symbol	Parameter	Min.	Max.	-1 Min.	-1 Max.	-2 Min.	-2 Max.	Unit	Test Condition
t_{CY}[3]	Clock Period	0.48	2.0	0.32	2.0	0.38	2.0	μsec	
t_r, t_f	Clock Rise and Fall Time	0	50	0	25	0	50	nsec	
$t_{\phi 1}$	ϕ_1 Pulse Width	60		50		60		nsec	
$t_{\phi 2}$	ϕ_2 Pulse Width	220		145		175		nsec	
t_{D1}	Delay ϕ_1 to ϕ_2	0		0		0		nsec	
t_{D2}	Delay ϕ_2 to ϕ_1	70		60		70		nsec	
t_{D3}	Delay ϕ_1 to ϕ_2 Leading Edges	80		60		70		nsec	
t_{DA}[2]	Address Output Delay From ϕ_2		200		150		175	nsec	C_L = 100 pF
t_{DD}[2]	Data Output Delay From ϕ_2		220		180		200	nsec	
t_{DC}[2]	Signal Output Delay From ϕ_2 or ϕ_2 (SYNC, WR, WAIT, HLDA)		120		110		120	nsec	C_L = 50 pF
t_{DF}[2]	DBIN Delay From ϕ_2	25	140	25	130	25	140	nsec	
t_{DI}[1]	Delay for Input Bus to Enter Input Mode		t_{DF}		t_{DF}		t_{DF}	nsec	
t_{DS1}	Data Setup Time During ϕ_1 and DBIN	30		10		20		nsec	

WAVEFORMS

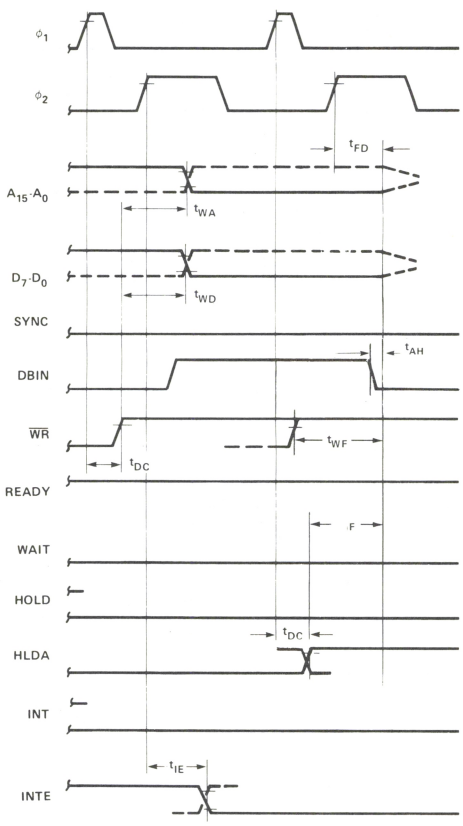
(Note: Timing measurements are made at the following reference voltages: CLOCK "1" = 8.0V "0" = 1.0V; INPUTS "1" = 3.3V, "0" = 0.8V; OUTPUTS "1" = 2.0V, "0" = 0.8V.)



A.C. CHARACTERISTICS (8080A)

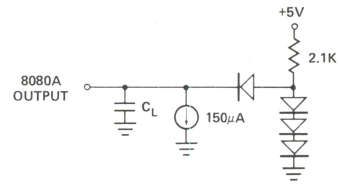
T_A = 0°C to 70°C, V_{DD} = +12V ± 5%, V_{CC} = +5V ± 5%, V_{BB} = -5V ± 5%, V_{SS} = 0V, Unless Otherwise Noted

Symbol	Parameter	Min.	Max.	-1 Min.	-1 Max.	-2 Min.	-2 Max.	Unit	Test Condition
t_{DS2}	Data Setup Time to ϕ_2 During DBIN	150		120		130		nsec	
t_{DH}[1]	Data Holt time From ϕ_2 During DBIN	[1]		[1]		[1]		nsec	
t_{IE}[2]	INTE Output Delay From ϕ_2		200		200		200	nsec	C_L = 50 pF
t_{RS}	READY Setup Time During ϕ_2	120		90		90		nsec	
t_{HS}	HOLD Setup Time to ϕ_2	140		120		120		nsec	
t_{IS}	INT Setup Time During ϕ_2	120		100		100		nsec	
t_H	Hold Time From ϕ_2 (READY, INT, HOLD)	0		0		0		nsec	
t_{FD}	Delay to Float During Hold (Address and Data Bus)		120		120		120	nsec	
t_{AW}[2]	Address Stable Prior to WR	[5]		[5]		[5]		nsec	C_L = 100 pF: Address, Data C_L = 50 pF: $\overline{WR}$,HLDA,DBIN
t_{DW}[2]	Output Data Stable Prior to WR	[6]		[6]		[6]		nsec	
t_{WD}[2]	Output Data Stable From WR	[7]		[7]		[7]		nsec	
t_{WA}[2]	Address Stable From WR	[7]		[7]		[7]		nsec	
t_{HF}[2]	HLDA to Float Delay	[8]		[8]		[8]		nsec	
t_{WF}[2]	WR to Float Delay	[9]		[9]		[9]		nsec	
t_{AH}[2]	Address Hold Time After DBIN During HLDA	− 20		− 20		− 20		nsec	



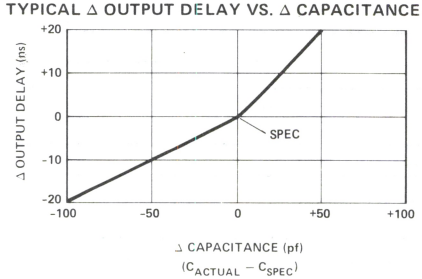
NOTES: (Parenthesis gives -1, -2 specifications, respectively)

1. Data input should be enabled with DBIN status. No bus conflict can then occur and data hold time is assured. t_{DH} = 50 ns or t_{DF}, whichever is less.
2. Load Circuit.



3. $t_{CY} = t_{D3} + t_{r\phi2} + t_{\phi2} + t_{f\phi2} + t_{D2} + t_{r\phi1} \geq 480$ ns (− 1:320 ns, − 2:380 ns).

TYPICAL Δ OUTPUT DELAY VS. Δ CAPACITANCE



4. The following are relevant when interfacing the 8080A to devices having V_{IH} = 3.3V:
   a) Maximum output rise time from .8V to 3.3V = 100ns @ C_L = SPEC.
   b) Output delay when measured to 3.0V = SPEC +60ns @ C_L = SPEC.
   c) If $C_L \neq$ SPEC, add .6ns/pF if $C_L > C_{SPEC}$, subtract .3ns/pF (from modified delay) if $C_L < C_{SPEC}$.
5. $t_{AW} = 2\,t_{CY} - t_{D3} - t_{r\phi2} - 140$ ns (− 1:110 ns, − 2:130 ns).
6. $t_{DW} = t_{CY} - t_{D3} - t_{r\phi2} - 170$ ns (− 1:150 ns, − 2:170 ns).
7. If not HLDA, $t_{WD} = t_{WA} = t_{D3} + t_{r\phi2}$ +10ns. If HLDA, $t_{WD} = t_{WA} = t_{WF}$.
8. $t_{HF} = t_{D3} + t_{r\phi2}$ -50ns.
9. $t_{WF} = t_{D3} + t_{r\phi2}$ -10ns
10. Data in must be stable for this period during DBIN · T_3. Both t_{DS1} and t_{DS2} must be satisfied.
11. Ready signal must be stable for this period during T_2 or T_W. (Must be externally synchronized.)
12. Hold signal must be stable for this period during T_2 or T_W when entering hold mode, and during T_3, T_4, T_5 and T_{WH} when in hold mode. (External synchronization is not required.)
13. Interrupt signal must be stable during this period of the last clock cycle of any instruction in order to be recognized on the following instruction. (External synchronization is not required.)
14. This timing diagram shows timing relationships only; it does not represent any specific machine cycle.

INSTRUCTION SET

The accumulator group instructions include arithmetic and logical operators with direct, indirect, and immediate addressing modes.

Move, load, and store instruction groups provide the ability to move either 8 or 16 bits of data between memory, the six working registers and the accumulator using direct, indirect, and immediate addressing modes.

The ability to branch to different portions of the program is provided with jump, jump conditional, and computed jumps. Also the ability to call to and return from subroutines is provided both conditionally and unconditionally. The RESTART (or single byte call instruction) is useful for interrupt vector operation.

Double precision operators such as stack manipulation and double add instructions extend both the arithmetic and interrupt handling capability of the 8080A. The ability to increment and decrement memory, the six general registers and the accumulator is provided as well as extended increment and decrement instructions to operate on the register pairs and stack pointer. Further capability is provided by the ability to rotate the accumulator left or right through or around the carry bit.

Input and output may be accomplished using memory addresses as I/O ports or the directly addressed I/O provided for in the 8080A instruction set.

The following special instruction group completes the 8080A instruction set: the NOP instruction, HALT to stop processor execution and the DAA instructions provide decimal arithmetic capability. STC allows the carry flag to be directly set, and the CMC instruction allows it to be complemented. CMA complements the contents of the accumulator and XCHG exchanges the contents of two 16-bit register pairs directly.

Data and Instruction Formats

Data in the 8080A is stored in the form of 8-bit binary integers. All data transfers to the system data bus will be in the same format.

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0

DATA WORD

The program instructions may be one, two, or three bytes in length. Multiple byte instructions must be stored in successive words in program memory. The instruction formats then depend on the particular operation executed.

One Byte Instructions

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	OP CODE

TYPICAL INSTRUCTIONS

Register to register, memory reference, arithmetic or logical, rotate, return, push, pop, enable or disable Interrupt instructions

Two Byte Instructions

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	
D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	OP CODE
D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	OPERAND

Immediate mode or I/O instructions

Three Byte Instructions

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	
D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	OP CODE
D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	LOW ADDRESS OR OPERAND 1
D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	HIGH ADDRESS OR OPERAND 2

Jump, call or direct load and store instructions

For the 8080A a logic "1" is defined as a high level and a logic "0" is defined as a low level.

8080 INSTRUCTION SET

Summary of Processor Instructions

Mnemonic	Description	Instruction Code[1] D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	Clock[2] Cycles
MOVE, LOAD, AND STORE										
MOVr1,r2	Move register to register	0	1	D	D	D	S	S	S	5
MOV M,r	Move register to memory	0	1	1	1	0	S	S	S	7
MOV r,M	Move memory to register	0	1	D	D	D	1	1	0	7
MVI r	Move immediate register	0	0	D	D	D	1	1	0	7
MVI M	Move immediate memory	0	0	1	1	0	1	1	0	10
LXI B	Load immediate register Pair B & C	0	0	0	0	0	0	0	1	10
LXI D	Load immediate register Pair D & E	0	0	0	1	0	0	0	1	10
LXI H	Load immediate register Pair H & L	0	0	1	0	0	0	0	1	10
STAX B	Store A indirect	0	0	0	0	0	0	1	0	7
STAX D	Store A indirect	0	0	0	1	0	0	1	0	7
LDAX B	Load A indirect	0	0	0	0	1	0	1	0	7
LDAX D	Load A indirect	0	0	0	1	1	0	1	0	7
STA	Store A direct	0	0	1	1	0	0	1	0	13
LDA	Load A direct	0	0	1	1	1	0	1	0	13
SHLD	Store H & L direct	0	0	1	0	0	0	1	0	16
LHLD	Load H & L direct	0	0	1	0	1	0	1	0	16
XCHG	Exchange D & E, H & L Registers	1	1	1	0	1	0	1	1	4
STACK OPS										
PUSH B	Push register Pair B & C on stack	1	1	0	0	0	1	0	1	11
PUSH D	Push register Pair D & E on stack	1	1	0	1	0	1	0	1	11
PUSH H	Push register Pair H & L on stack	1	1	1	0	0	1	0	1	11
PUSH PSW	Push A and Flags on stack	1	1	1	1	0	1	0	1	11
POP B	Pop register Pair B & C off stack	1	1	0	0	0	0	0	1	10
POP D	Pop register Pair D & E off stack	1	1	0	1	0	0	0	1	10
POP H	Pop register Pair H & L off stack	1	1	1	0	0	0	0	1	10
POP PSW	Pop A and Flags off stack	1	1	1	1	0	0	0	1	10
XTHL	Exchange top of stack, H & L	1	1	1	0	0	0	1	1	18
SPHL	H & L to stack pointer	1	1	1	1	1	0	0	1	5
LXI SP	Load immediate stack pointer	0	0	1	1	0	0	0	1	10
INX SP	Increment stack pointer	0	0	1	1	0	0	1	1	5
DCX SP	Decrement stack pointer	0	0	1	1	1	0	1	1	5
JUMP										
JMP	Jump unconditional	1	1	0	0	0	0	1	1	10
JC	Jump on carry	1	1	0	1	1	0	1	0	10
JNC	Jump on no carry	1	1	0	1	0	0	1	0	10
JZ	Jump on zero	1	1	0	0	1	0	1	0	10
JNZ	Jump on no zero	1	1	0	0	0	0	1	0	10
JP	Jump on positive	1	1	1	1	0	0	1	0	10
JM	Jump on minus	1	1	1	1	1	0	1	0	10
JPE	Jump on parity even	1	1	1	0	1	0	1	0	10
JPO	Jump on parity odd	1	1	1	0	0	0	1	0	10
PCHL	H & L to program counter	1	1	1	0	1	0	0	1	5
CALL										
CALL	Call unconditional	1	1	0	0	1	1	0	1	17
CC	Call on carry	1	1	0	1	1	1	0	0	11/17
CNC	Call on no carry	1	1	0	1	0	1	0	0	11/17
CZ	Call on zero	1	1	0	0	1	1	0	0	11/17
CNZ	Call on no zero	1	1	0	0	0	1	0	0	11/17
CP	Call on positive	1	1	1	1	0	1	0	0	11/17
CM	Call on minus	1	1	1	1	1	1	0	0	11/17
CPE	Call on parity even	1	1	1	0	1	1	0	0	11/17
CPO	Call on parity odd	1	1	1	0	0	1	0	0	11/17
RETURN										
RET	Return	1	1	0	0	1	0	0	1	10
RC	Return on carry	1	1	0	1	1	0	0	0	5/11
RNC	Return on no carry	1	1	0	1	0	0	0	0	5/11
RZ	Return on zero	1	1	0	0	1	0	0	0	5/11
RNZ	Return on no zero	1	1	0	0	0	0	0	0	5/11
RP	Return on positive	1	1	1	1	0	0	0	0	5/11
RM	Return on minus	1	1	1	1	1	0	0	0	5/11
RPE	Return on parity even	1	1	1	0	1	0	0	0	5/11
RPO	Return on parity odd	1	1	1	0	0	0	0	0	5/11
RESTART										
RST	Restart	1	1	A	A	A	1	1	1	11
INCREMENT AND DECREMENT										
INR r	Increment register	0	0	D	D	D	1	0	0	5
DCR r	Decrement register	0	0	D	D	D	1	0	1	5
INR M	Increment memory	0	0	1	1	0	1	0	0	10
DCR M	Decrement memory	0	0	1	1	0	1	0	1	10
INX B	Increment B & C registers	0	0	0	0	0	0	1	1	5
INX D	Increment D & E registers	0	0	0	1	0	0	1	1	5
INX H	Increment H & L registers	0	0	1	0	0	0	1	1	5
DCX B	Decrement B & C	0	0	0	0	1	0	1	1	5
DCX D	Decrement D & E	0	0	0	1	1	0	1	1	5
DCX H	Decrement H & L	0	0	1	0	1	0	1	1	5
ADD										
ADD r	Add register to A	1	0	0	0	0	S	S	S	4
ADC r	Add register to A with carry	1	0	0	0	1	S	S	S	4
ADD M	Add memory to A	1	0	0	0	0	1	1	0	7
ADC M	Add memory to A with carry	1	0	0	0	1	1	1	0	7
ADI	Add immediate to A	1	1	0	0	0	1	1	0	7
ACI	Add immediate to A with carry	1	1	0	0	1	1	1	0	7
DAD B	Add B & C to H & L	0	0	0	0	1	0	0	1	10
DAD D	Add D & E to H & L	0	0	0	1	1	0	0	1	10
DAD H	Add H & L to H & L	0	0	1	0	1	0	0	1	10
DAD SP	Add stack pointer to H & L	0	0	1	1	1	0	0	1	10

NOTES: 1. DDD or SSS: B: 000, C: 001, D: 010, E: 011, H: 100, L: 101, Memory: 110, A: 111

2. Two possible cycle times, (6/12) indicate instruction cycles dependent on condition flags.

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Summary of Processor Instructions (Cont.)

Mnemonic	Description	Instruction Code[1] D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	Clock[2] Cycles
SUBTRACT										
SUB r	Subtract register from A	1	0	0	1	0	S	S	S	4
SBB r	Subtract register from A with borrow	1	0	0	1	1	S	S	S	4
SUB M	Subtract memory from A	1	0	0	1	0	1	1	0	7
SBB M	Subtract memory from A with borrow	1	0	0	1	1	1	1	0	7
SUI	Subtract immediate from A	1	1	0	1	0	1	1	0	7
SBI	Subtract immediate from A with borrow	1	1	0	1	1	1	1	0	7
LOGICAL										
ANA r	And register with A	1	0	1	0	0	S	S	S	4
XRA r	Exclusive Or register with A	1	0	1	0	1	S	S	S	4
ORA r	Or register with A	1	0	1	1	0	S	S	S	4
CMP r	Compare register with A	1	0	1	1	1	S	S	S	4
ANA M	And memory with A	1	0	1	0	0	1	1	0	7
XRA M	Exclusive Or memory with A	1	0	1	0	1	1	1	0	7
ORA M	Or memory with A	1	0	1	1	0	1	1	0	7
CMP M	Compare memory with A	1	0	1	1	1	1	1	0	7
ANI	And immediate with A	1	1	1	0	0	1	1	0	7
XRI	Exclusive Or immediate with A	1	1	1	0	1	1	1	0	7
ORI	Or immediate with A	1	1	1	1	0	1	1	0	7
CPI	Compare immediate with A	1	1	1	1	1	1	1	0	7
ROTATE										
RLC	Rotate A left	0	0	0	0	0	1	1	1	4
RRC	Rotate A right	0	0	0	0	1	1	1	1	4
RAL	Rotate A left through carry	0	0	0	1	0	1	1	1	4
RAR	Rotate A right through carry	0	0	0	1	1	1	1	1	4
SPECIALS										
CMA	Complement A	0	0	1	0	1	1	1	1	4
STC	Set carry	0	0	1	1	0	1	1	1	4
CMC	Complement carry	0	0	1	1	1	1	1	1	4
DAA	Decimal adjust A	0	0	1	0	0	1	1	1	4
INPUT/OUTPUT										
IN	Input	1	1	0	1	1	0	1	1	10
OUT	Output	1	1	0	1	0	0	1	1	10
CONTROL										
EI	Enable Interrupts	1	1	1	1	1	0	1	1	4
DI	Disable Interrupt	1	1	1	1	0	0	1	1	4
NOP	No-operation	0	0	0	0	0	0	0	0	4
HLT	Halt	0	1	1	1	0	1	1	0	7

NOTES: 1. DDD or SSS: B=000, C=001, D=010, E=011, H=100, L=101, Memory=110, A=111.
2. Two possible cycle times, (6/12) indicate instruction cycles dependent on condition flags.

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8224
CLOCK GENERATOR AND DRIVER FOR 8080A CPU

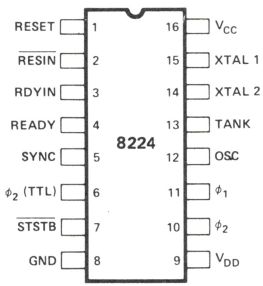
- **Single Chip Clock Generator/Driver for 8080A CPU**
- **Power-Up Reset for CPU**
- **Ready Synchronizing Flip-Flop**
- **Advanced Status Strobe**
- **Oscillator Output for External System Timing**
- **Crystal Controlled for Stable System Operation**
- **Reduces System Package Count**

The Intel® 8224 is a single chip clock generator/driver for the 8080A CPU. It is controlled by a crystal, selected by the designer to meet a variety of system speed requirements.

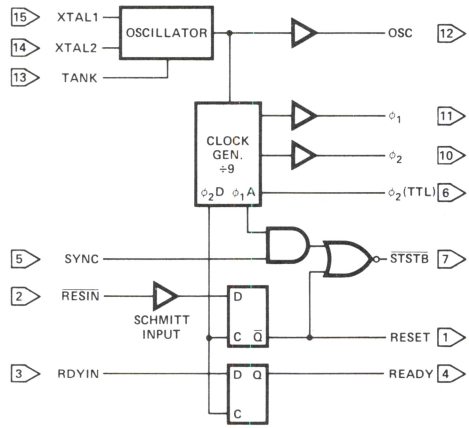
Also included are circuits to provide power-up reset, advance status strobe, and synchronization of ready.

The 8224 provides the designer with a significant reduction of packages used to generate clocks and timing for 8080A.

PIN CONFIGURATION



BLOCK DIAGRAM



PIN NAMES

RESIN	RESET INPUT
RESET	RESET OUTPUT
RDYIN	READY INPUT
READY	READY OUTPUT
SYNC	SYNC INPUT
STSTB	STATUS STB (ACTIVE LOW)
ϕ_1	8080 CLOCKS
ϕ_2	8080 CLOCKS

XTAL 1	CONNECTIONS FOR CRYSTAL
XTAL 2	CONNECTIONS FOR CRYSTAL
TANK	USED WITH OVERTONE XTAL
OSC	OSCILLATOR OUTPUT
ϕ_2 (TTL)	ϕ_2 CLK (TTL LEVEL)
V_{CC}	+5V
V_{DD}	+12V
GND	0V

ABSOLUTE MAXIMUM RATINGS*

Temperature Under Bias . . . . . 0°C to 70°C
Storage Temperature . . . . . −65°C to 150°C
Supply Voltage, V_{CC} . . . . . −0.5V to +7V
Supply Voltage, V_{DD} . . . . . −0.5V to +13.5V
Input Voltage . . . . . −1.5V to +7V
Output Current 100mA

**COMMENT: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

D.C. CHARACTERISTICS

T_A = 0°C to 70°C; V_{CC} = +5.0V ±5%; V_{DD} = +12V ±5%.

Symbol	Parameter	Limits Min.	Limits Typ.	Limits Max.	Units	Test Conditions
I_F	Input Current Loading			-.25	mA	V_F = .45V
I_R	Input Leakage Current			10	μA	V_R = 5.25V
V_C	Input Forward Clamp Voltage			1.0	V	I_C = -5mA
V_{IL}	Input "Low" Voltage			.8	V	V_{CC} = 5.0V
V_{IH}	Input "High" Voltage	2.6 2.0			V	Reset Input All Other Inputs
V_{IH}-V_{IL}	RESIN Input Hysteresis	.25			V	V_{CC} = 5.0V
V_{OL}	Output "Low" Voltage			.45 .45	V V	(ϕ_1,ϕ_2), Ready, Reset, $\overline{STSTB}$ I_{OL} =2.5mA All Other Outputs I_{OL} = 15mA
V_{OH}	Output "High" Voltage ϕ_1 , ϕ_2 READY, RESET All Other Outputs	 9.4 3.6 2.4			 V V V	 I_{OH} = -100μA I_{OH} = -100μA I_{OH} = -1mA
I_{SC}[1]	Output Short Circuit Current (All Low Voltage Outputs Only)	-10		-60	mA	V_O = 0V V_{CC} = 5.0V
I_{CC}	Power Supply Current			115	mA	
I_{DD}	Power Supply Current			12	mA	

Note: 1. Caution, ϕ_1 and ϕ_2 output drivers do not have short circuit protection

Crystal Requirements

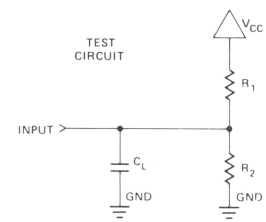
Tolerance: 0.005% at 0°C-70°C
Resonance: Series (Fundamental)*
Load Capacitance: 20-35 pF
Equivalent Resistance: 75-20 ohms
Power Dissipation (Min): 4 mW

*With tank circuit use 3rd overtone mode.

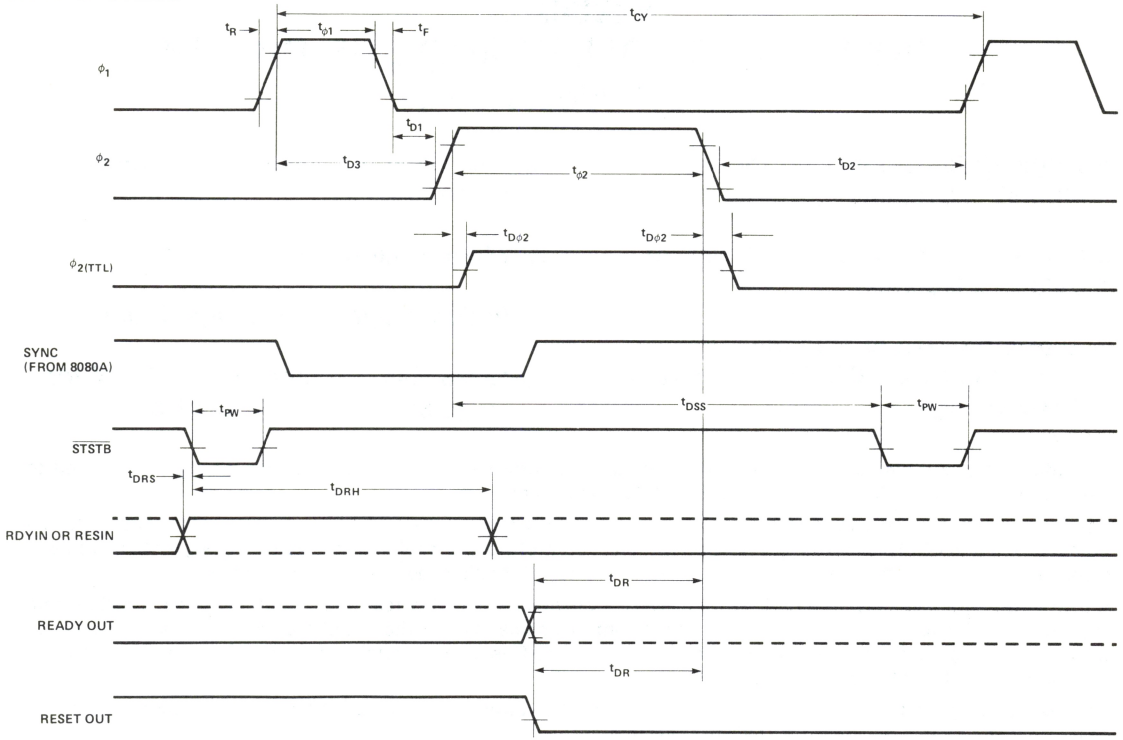
A.C. CHARACTERISTICS

V_{CC} = +5.0V ± 5%; V_{DD} = +12.0V ± 5%; T_A = 0°C to 70°C

Symbol	Parameter	Limits			Units	Test Conditions
		Min.	Typ.	Max.		
$t_{\phi 1}$	ϕ_1 Pulse Width	$\frac{2tcy}{9}$ - 20ns			ns	C_L = 20pF to 50pF
$t_{\phi 2}$	ϕ_2 Pulse Width	$\frac{5tcy}{9}$ - 35ns				
t_{D1}	ϕ_1 to ϕ_2 Delay	0				
t_{D2}	ϕ_2 to ϕ_1 Delay	$\frac{2tcy}{9}$ - 14ns				
t_{D3}	ϕ_1 to ϕ_2 Delay	$\frac{2tcy}{9}$		$\frac{2tcy}{9}$ + 20ns		
t_R	ϕ_1 and ϕ_2 Rise Time			20		
t_F	ϕ_1 and ϕ_2 Fall Time			20		
$t_{D\phi 2}$	ϕ_2 to ϕ_2 (TTL) Delay	-5		+15	ns	ϕ_2TTL,CL=30 R_1=300Ω R_2=600Ω
t_{DSS}	ϕ_2 to $\overline{STSTB}$ Delay	$\frac{6tcy}{9}$ - 30ns		$\frac{6tcy}{9}$		$\overline{STSTB}$,CL=15pF R_1 = 2K R_2 = 4K
t_{PW}	$\overline{STSTB}$ Pulse Width	$\frac{tcy}{9}$ - 15ns				
t_{DRS}	RDYIN Setup Time to Status Strobe	50ns - $\frac{4tcy}{9}$				
t_{DRH}	RDYIN Hold Time After $\overline{STSTB}$	$\frac{4tcy}{9}$				
t_{DR}	RDYIN or RESIN to ϕ_2 Delay	$\frac{4tcy}{9}$ - 25ns				Ready & Reset CL=10pF R_1=2K R_2=4K
t_{CLK}	CLK Period		$\frac{tcy}{9}$			
f_{max}	Maximum Oscillating Frequency			27	MHz	
C_{in}	Input Capacitance			8	pF	V_{CC}=+5.0V V_{DD}=+12V V_{BIAS}=2.5V f=1MHz



WAVEFORMS



VOLTAGE MEASUREMENT POINTS: ϕ_1, ϕ_2 Logic "0" = 1.0V, Logic "1" = 8.0V. All other signals measured at 1.5V.

EXAMPLE:

A.C. CHARACTERISTICS (For t_{CY} = 488.28 ns)

T_A = 0°C to 70°C; V_{DD} = +5V ±5%; V_{DD} = +12V ±5%.

Symbol	Parameter	Limits Min.	Typ.	Max.	Units	Test Conditions
$t_{\phi 1}$	ϕ_1 Pulse Width	89			ns	t_{CY}=488.28ns
$t_{\phi 2}$	ϕ_2 Pulse Width	236			ns	
t_{D1}	Delay ϕ_1 to ϕ_2	0			ns	
t_{D2}	Delay ϕ_2 to ϕ_1	95			ns	ϕ_1 & ϕ_2 Loaded to C_L = 20 to 50pF
t_{D3}	Delay ϕ_1 to ϕ_2 Leading Edges	109		129	ns	
t_r	Output Rise Time			20	ns	
t_f	Output Fall Time			20	ns	
t_{DSS}	ϕ_2 to $\overline{STSTB}$ Delay	296		326	ns	
$t_{D\phi 2}$	ϕ_2 to ϕ_2 (TTL) Delay	-5		+15	ns	
t_{PW}	Status Strobe Pulse Width	40			ns	Ready & Reset Loaded to 2mA/10pF
t_{DRS}	RDYIN Setup Time to $\overline{STSTB}$	-167			ns	
t_{DRH}	RDYIN Hold Time after $\overline{STSTB}$	217			ns	All measurements referenced to 1.5V unless specified otherwise.
t_{DR}	READY or RESET to ϕ_2 Delay	192			ns	
f_{MAX}	Oscillator Frequency			18.432	MHz	

8228/8238
SYSTEM CONTROLLER AND BUS DRIVER FOR 8080A CPU

- **Single Chip System Control for MCS-80™ Systems**
- **Built-In Bidirectional Bus Driver for Data Bus Isolation**
- **Allows the Use of Multiple Byte Instructions (e.g. CALL) for Interrupt Acknowledge**
- **User Selected Single Level Interrupt Vector (RST 7)**
- **28-Pin Dual In-Line Package**
- **Reduces System Package Count**
- ***8238 Has Advanced IOW/MEMW for Large System Timing Control**

The Intel® 8228 is a single chip system controller and bus driver for MCS-80. It generates all signals required to directly interface MCS-80 family RAM, ROM, and I/O components.

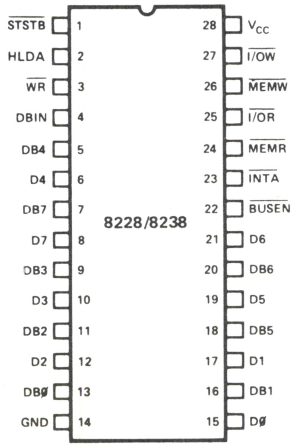
A bidirectional bus driver is included to provide high system TTL fan-out. It also provides isolation of the 8080 data bus from memory and I/O. This allows for the optimization of control signals, enabling the systems designer to use slower memory and I/O. The isolation of the bus driver also provides for enhanced system noise immunity.

A user selected single level interrupt vector (RST 7) is provided to simplify real time, interrupt driven, small system requirements. The 8228 also generates the correct control signals to allow the use of multiple byte instructions (e.g., CALL) in response to an interrupt acknowledge by the 8080A. This feature permits large, interrupt driven systems to have an unlimited number of interrupt levels.

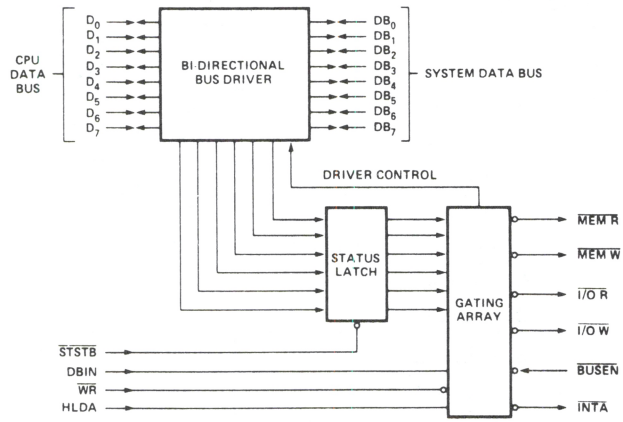
The 8228 is designed to support a wide variety of system bus structures and also reduce system package count for cost effective, reliable design of the MCS-80 systems.

Note: The specifications for the 3228/3238 are identical with those for the 8228/8238

PIN CONFIGURATION



BLOCK DIAGRAM



PIN NAMES

D7-D0	DATA BUS (8080 SIDE)	INTA	INTERRUPT ACKNOWLEDGE
DB7-DB0	DATA BUS (SYSTEM SIDE)	HLDA	HLDA (FROM 8080)
I/OR	I/O READ	WR	WR (FROM 8080)
I/OW	I/O WRITE	BUSEN	BUS ENABLE INPUT
MEMR	MEMORY READ	STSTB	STATUS STROBE (FROM 8224)
MEMW	MEMORY WRITE	Vcc	+5V
DBIN	DBIN (FROM 8080)	GND	0 VOLTS

ABSOLUTE MAXIMUM RATINGS*

Temperature Under Bias ..... – 0°C to 70°C
Storage Temperature ..... – 65°C to 150°C
Supply Voltage, V_{CC} ..... – 0.5V to + 7V
Input Voltage ..... – 1.5V to + 7V
Output Current ..... 100 mA

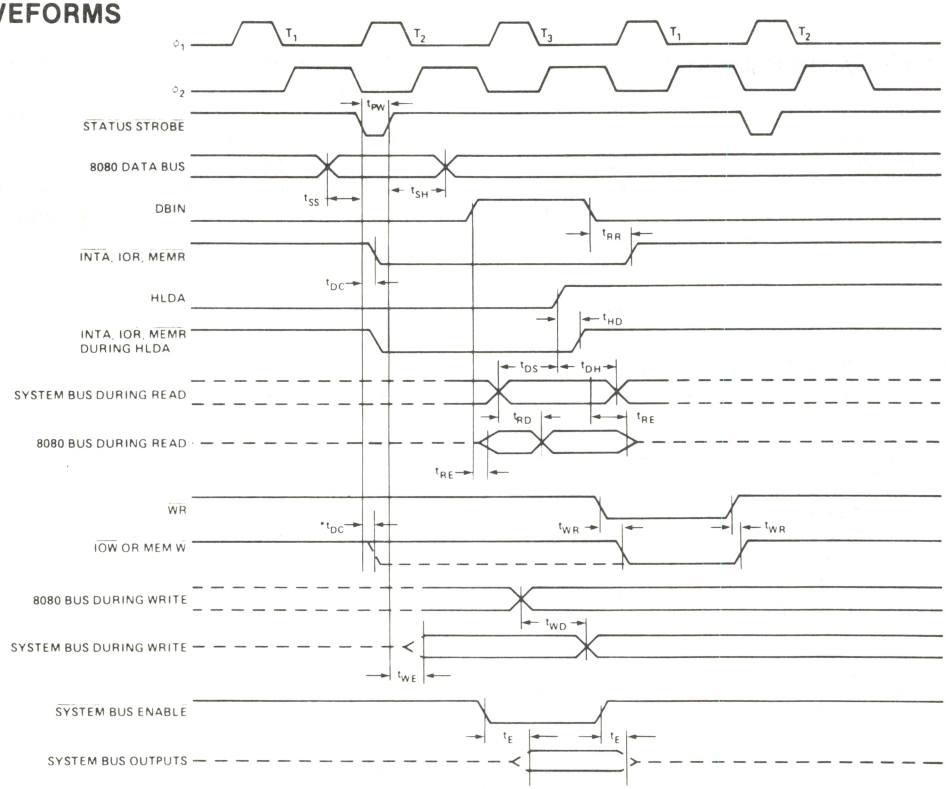
**COMMENT: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

D.C. CHARACTERISTICS T_A = 0°C to 70°C; V_{CC} = 5V ±5%.

Symbol	Parameter	Limits Min.	Typ.[1]	Max.	Unit	Test Conditions
V_C	Input Clamp Voltage, All Inputs		.75	-1.0	V	V_{CC}=4.75V; I_C=-5mA
I_F	Input Load Current, $\overline{STSTB}$			500	μA	V_{CC} = 5.25V
	D_2 & D_6			750	μA	V_F = 0.45V
	D_0, D_1, D_4, D_5, & D_7			250	μA	
	All Other Inputs			250	μA	
I_R	Input Leakage Current $\overline{STSTB}$			100	μA	V_{CC} = 5.25V
	DB_0-DB_7			20	μA	V_R = 5.25V
	All Other Inputs			100	μA	
V_{TH}	Input Threshold Voltage, All Inputs	0.8		2.0	V	V_{CC} = 5V
I_{CC}	Power Supply Current		140	190	mA	V_{CC}=5.25V
V_{OL}	Output Low Voltage, D_0-D_7			.45	V	V_{CC}=4.75V; I_{OL}=2mA
	All Other Outputs			.45	V	I_{OL} = 10mA
V_{OH}	Output High Voltage, D_0-D_7	3.6	3.8		V	V_{CC}=4.75V; I_{OH}=-10μA
	All Other Outputs	2.4			V	I_{OH} = -1mA
I_{OS}	Short Circuit Current, All Outputs	15		90	mA	V_{CC}=5V
$I_{O(off)}$	Off State Output Current, All Control Outputs			100	μA	V_{CC}=5.25V; V_O=5.25
				-100	μA	V_O=.45V
I_{INT}	INTA Current			5	mA	(See Figure below)

Note 1: Typical values are for T_A = 25°C and nominal supply voltages.

WAVEFORMS



VOLTAGE MEASUREMENT POINTS: D_0-D_7 (when outputs) Logic "0" = 0.8V, Logic "1" = 3.0V. All other signals measured at 1.5V.

*ADVANCED $\overline{IOW}$/$\overline{MEMW}$ FOR 8238 ONLY.

A.C. CHARACTERISTICS $T_A = 0°C$ to $70°C$, $V_{CC} = 5V \pm 5\%$

Symbol	Parameter	Limits		Units	Condition
		Min.	Max.		
t_{PW}	Width of Status Strobe	22		ns	
t_{SS}	Setup Time, Status Inputs D_0-D_7	8		ns	
t_{SH}	Hold Time, Status Inputs D_0-D_7	5		ns	
t_{DC}	Delay from $\overline{STSTB}$ to any Control Signal	20	60	ns	C_L = 100pF
t_{RR}	Delay from DBIN to Control Outputs		30	ns	C_L = 100pF
t_{RE}	Delay from DBIN to Enable/Disable 8080 Bus		45	ns	C_L = 25pF
t_{RD}	Delay from System Bus to 8080 Bus during Read		30	ns	C_L = 25pF
t_{WR}	Delay from $\overline{WR}$ to Control Outputs	5	45	ns	C_L = 100pF
t_{WE}	Delay to Enable System Bus DB_0-DB_7 after $\overline{STSTB}$		30	ns	C_L = 100pF
t_{WD}	Delay from 8080 Bus D_0-D_7 to System Bus DB_0-DB_7 during Write	5	40	ns	C_L = 100pF
t_E	Delay from $\overline{System\ Bus\ Enable}$ to System Bus DB_0-DB_7		30	ns	C_L = 100pF
t_{HD}	HLDA to Read Status Outputs		25	ns	
t_{DS}	Setup Time, System Bus Inputs to HLDA	10		ns	
t_{DH}	Hold Time, System Bus Inputs to HLDA	20		ns	C_L = 100pF

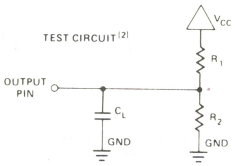
CAPACITANCE

This parameter is periodically sampled and not 100% tested.

Symbol	Parameter	Limits Min.	Typ.[1]	Max.	Unit
C_{IN}	Input Capacitance		8	12	pF
C_{OUT}	Output Capacitance Control Signals		7	15	pF
I/O	I/O Capacitance (D or DB)		8	15	pF

Test Conditions: NS: $V_{BIAS} = 2.5V$, $V_{CC} = 5.0V$, $T_A = 25°C$, f = 1MHz.

Note 2: For D_0-D_7: $R_1 = 4K\Omega$, $R_2 = \infty\Omega$, $C_L = 25pF$. For all other outputs: $R_1 = 500\Omega$, $R_2 = 1K\Omega$, $C_L = 100pF$.



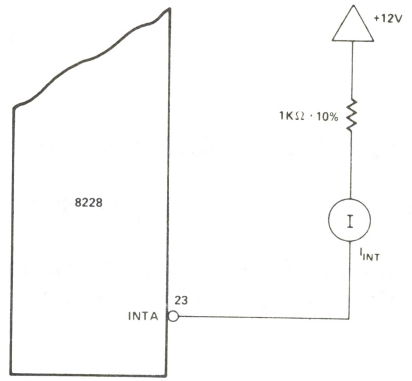


Figure 1. INTA Test Circuit (for RST 7)

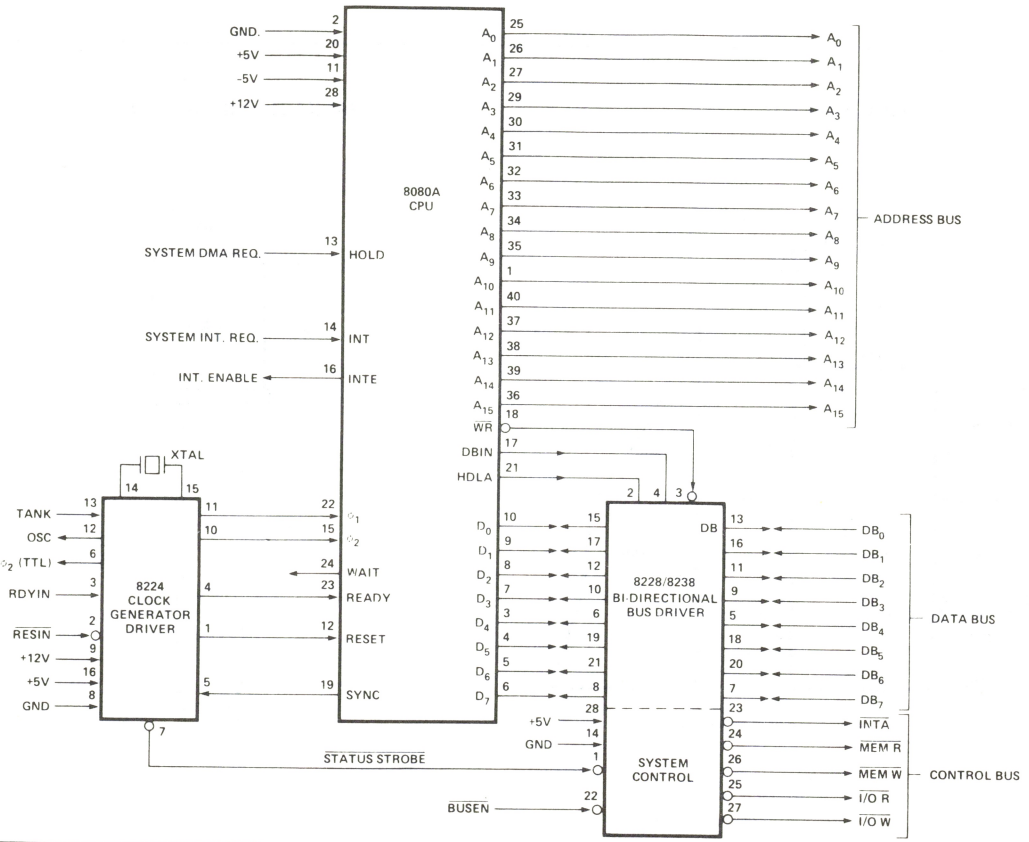


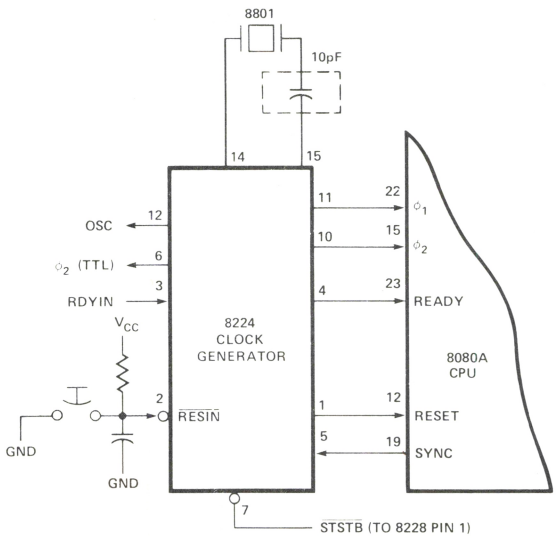
Figure 2. CPU Standard Interface

8801
CLOCK GENERATOR CRYSTAL FOR 8224/8080A

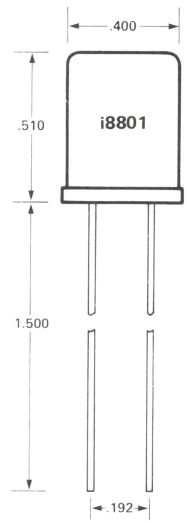
- **Specifically Selected for Intel® 8224**
- **18.432 MHz for 1.95 μs 8080A Cycle**
- **Simple Generation of all Standard Communication Baud Rates**
- **Frequency Deviation ±0.005%**
- **Fundamental Frequency Mode**
- **0°C to 70°C Operating Temperature**

The Intel® 8801 is a quartz crystal specifically selected to operate with the 8224 clock generator and the 8080A CPU. It resonates in the fundamental frequency mode at 18.432 MHz. This frequency allows the 8080A at full speed (T_{CY} = 488 ns) to have a cycle of 1.95 μs and also simplifies the generation of all standard communication baud rates. The 8801 crystal is exactly matched to the requirements of the 8080A/8224 and provides both high performance and system flexibility for the microcomputer designer.

8801 INTERFACE



PACKAGING INFORMATION



APPLICATIONS

The selection of 18.432 MHz provides the 8080A with clocks whose period is 488ns. This allows the 8080A to operate at very close to its maximum specified speed (480 ns). The 8224, when used with the 8801, outputs a signal on its OSC pin that is an approximately symetrical square wave at a frequency of 18.432 MHz. This frequency signal can be easily divided down to generate an accurate, stable baud rate clock that can be connected directly to the transmitter or receiver clocks of the 8251 USART. This feature allows the designer to support most standard communication interfaces with a minimum of extra hardware.

The chart below (Fig. 1) shows the equivalent baud rates that are generated with the corresponding dividers.

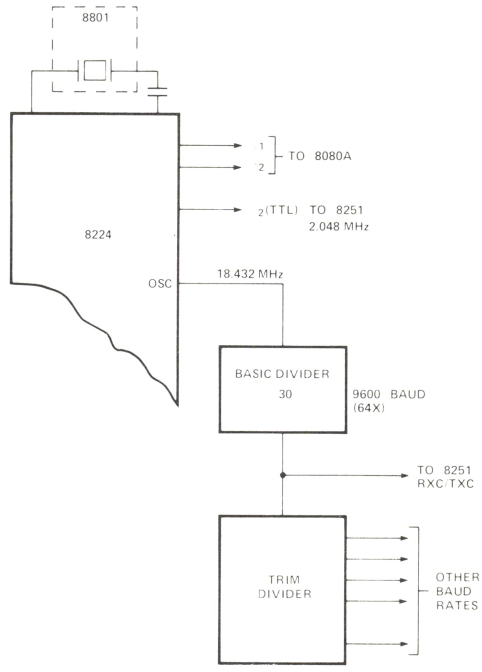


Figure 1. Block Diagram

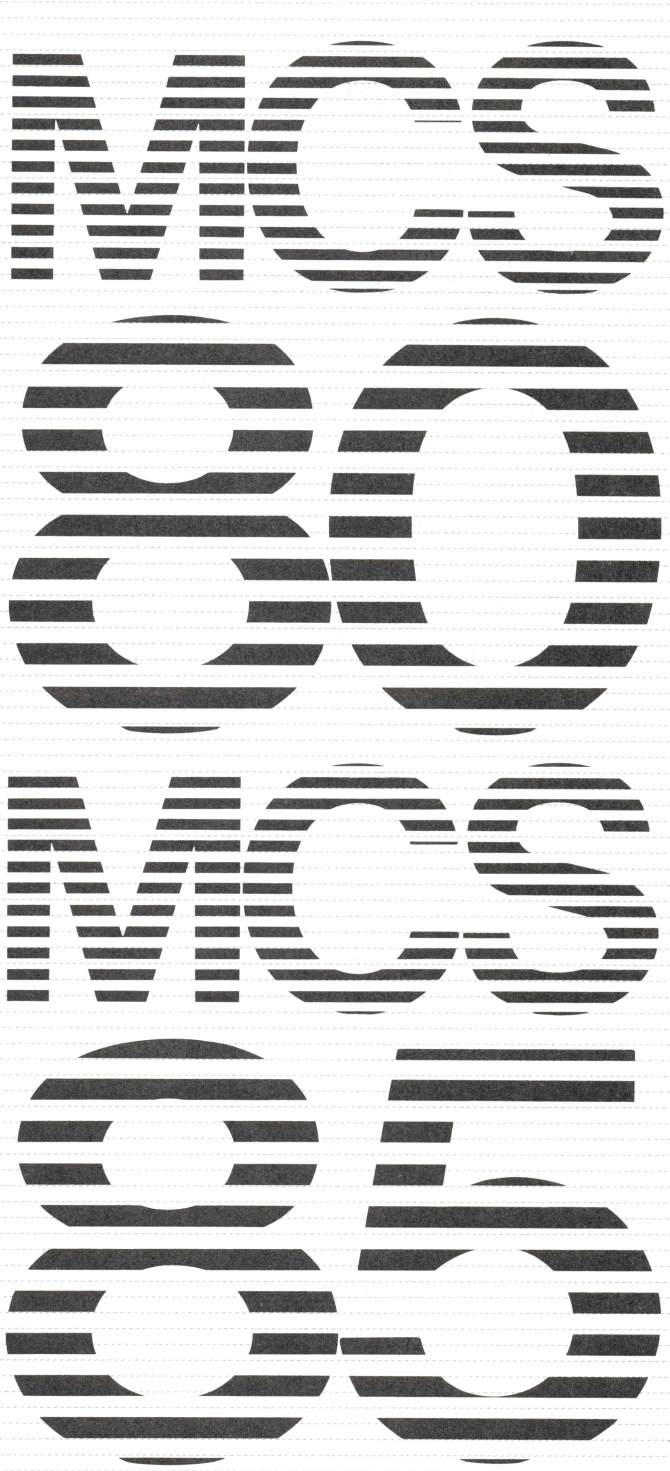
BAUD RATE 64x	BAUD RATE 16x	FREQUENCY	BASIC DIVIDER	PLUS TRIM DIVIDER
9600		614.4 KH	÷30	–
4800	19.2K	307.2 KH	÷30	÷2
2400	9600	153.6 KH	÷30	÷4
1200	4800	76.8 KH	÷30	÷8
600	2400	38.4 KH	÷30	÷16
300	1200	19.2 KH	÷30	÷32
	600	9.6 KH	÷30	÷64
	300	4.8 KH	÷30	÷128
*109.1		6.982 KH	÷30	÷88

*For 109.1 (64x) Baud rate divide 1200 Baud Frequency (76.8 KH) by 11.

Figure 2. Baud Rate Chart

ELECTRICAL CHARACTERISTICS

Recommended Drive Level 5mW
Type of Resonance . . . . . Series
Equivalent Resistance . . . . . 20 ohms
Maximum Shunt Capacity 7pF
Maximum Frequency Deviation
0° – 70°C . . . . . ±.005%
-55°– 125°C . . . . . ±.002%



Chapter 6

MCS-85™ MCS-80™

Systems Support Components

Peripherals

Static RAMs

ROMs-EPROMs

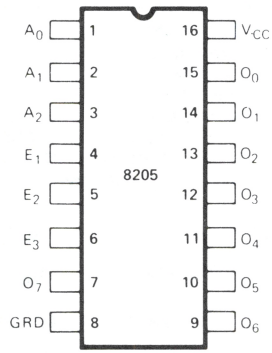
8205
HIGH SPEED 1 OUT OF 8 BINARY DECODER

- **I/O Port or Memory Selector**
- **Simple Expansion — Enable Inputs**
- **High Speed Schottky Bipolar Technology — 18 ns Max Delay**
- **Directly Compatible with TTL Logic Circuits**
- **Low Input Load Current — 0.25 mA Max, 1/6 Standard TTL Input Load**
- **Minimum Line Reflection — Low Voltage Diode Input Clamp**
- **Outputs Sink 10 mA Min**
- **16-Pin Dual In-Line Ceramic or Plastic Package**

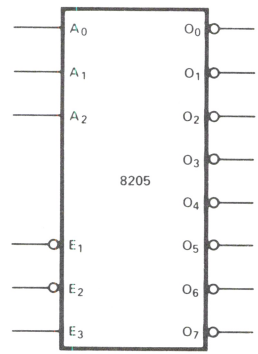
The Intel® 8205 decoder can be used for expansion of systems which utilize input ports, output ports, and memory components with active low chip select input. When the 8205 is enabled, one of its 8 outputs goes "low", thus a single row of a memory system is selected. The 3-chip enable inputs on the 8205 allow easy system expansion. For very large systems, 8205 decoders can be cascaded such that each decoder can drive 8 other decoders for arbitrary memory expansions.

The 8205 is packaged in a standard 16-pin dual in-line package, and its performance is specified over the temperature range of 0°C to +75°C, ambient. The use of Schottky barrier diode clamped transistors to obtain fast switching speeds results in higher performance than equivalent devices made with a gold diffusion process.

PIN CONFIGURATION



LOGIC SYMBOL



PIN NAMES

A_0-A_2	ADDRESS INPUTS
$\overline{E_1}$-$\overline{E_3}$	ENABLE INPUTS
$\overline{O_0}$-$\overline{O_7}$	DECODED OUTPUTS

ADDRESS			ENABLE			OUTPUTS							
A_0	A_1	A_2	E_1	E_2	E_3	0	1	2	3	4	5	6	7
L	L	L	L	L	H	L	H	H	H	H	H	H	H
H	L	L	L	L	H	H	L	H	H	H	H	H	H
L	H	L	L	L	H	H	H	L	H	H	H	H	H
H	H	L	L	L	H	H	H	H	L	H	H	H	H
L	L	H	L	L	H	H	H	H	H	L	H	H	H
H	L	H	L	L	H	H	H	H	H	H	L	H	H
L	H	H	L	L	H	H	H	H	H	H	H	L	H
H	H	H	L	L	H	H	H	H	H	H	H	H	L
X	X	X	L	L	L	H	H	H	H	H	H	H	H
X	X	X	H	L	L	H	H	H	H	H	H	H	H
X	X	X	L	H	L	H	H	H	H	H	H	H	H
X	X	X	H	H	L	H	H	H	H	H	H	H	H
X	X	X	H	L	H	H	H	H	H	H	H	H	H
X	X	X	L	H	H	H	H	H	H	H	H	H	H
X	X	X	H	H	H	H	H	H	H	H	H	H	H

FUNCTIONAL DESCRIPTION

Decoder

The 8205 contains a one out of eight binary decoder. It accepts a three bit binary code and by gating this input, creates an exclusive output that represents the value of the input code.

For example, if a binary code of 101 was present on the A0, A1 and A2 address input lines, and the device was enabled, an active low signal would appear on the $\overline{05}$ output line. Note that all of the other output pins are sitting at a logic high, thus the decoded output is said to be exclusive. The decoders outputs will follow the truth table shown below in the same manner for all other input variations.

Enable Gate

When using a decoder it is often necessary to gate the outputs with timing or enabling signals so that the exclusive output of the decoded value is synchronous with the overall system.

The 8205 has a built-in function for such gating. The three enable inputs ($\overline{E1}$, $\overline{E2}$, E3) are ANDed together and create a single enable signal for the decoder. The combination of both active "high" and active "low" device enable inputs provides the designer with a powerfully flexible gating function to help reduce package count in his system.

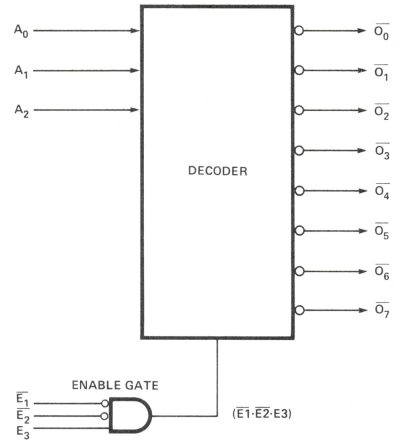


Figure 1. Enable Gate

ADDRESS			ENABLE			OUTPUTS							
A_0	A_1	A_2	E_1	E_2	E_3	0	1	2	3	4	5	6	7
L	L	L	L	L	H	L	H	H	H	H	H	H	H
H	L	L	L	L	H	H	L	H	H	H	H	H	H
L	H	L	L	L	H	H	H	L	H	H	H	H	H
H	H	L	L	L	H	H	H	H	L	H	H	H	H
L	L	H	L	L	H	H	H	H	H	L	H	H	H
H	L	H	L	L	H	H	H	H	H	H	L	H	H
L	H	H	L	L	H	H	H	H	H	H	H	L	H
H	H	H	L	L	H	H	H	H	H	H	H	H	L
X	X	X	L	L	L	H	H	H	H	H	H	H	H
X	X	X	H	L	L	H	H	H	H	H	H	H	H
X	X	X	L	H	L	H	H	H	H	H	H	H	H
X	X	X	H	H	L	H	H	H	H	H	H	H	H
X	X	X	H	L	H	H	H	H	H	H	H	H	H
X	X	X	L	H	H	H	H	H	H	H	H	H	H
X	X	X	H	H	H	H	H	H	H	H	H	H	H

APPLICATIONS OF THE 8205

The 8205 can be used in a wide variety of applications in microcomputer systems. I/O ports can be decoded from the address bus, chip select signals can be generated to select memory devices and the type of machine state such as in 8008 systems can be derived from a simple decoding of the state lines (S0, S1, S2) of the 8008 CPU.

I/O Port Decoder

Shown in the figure below is a typical application of the 8205. Address input lines are decoded by a group of 8205s (3). Each input has a binary weight. For example, A0 is assigned a value of 1 and is the LSB; A4 is assigned a value of 16 and is the MSB. By connecting them to the decoders as shown, an active low signal that is exclusive in nature and represents the value of the input address lines, is available at the outputs of the 8205s.

This circuit can be used to generate enable signals for I/O ports or any other decoder related application.

Note that no external gating is required to decode up to 24 exclusive devices and that a simple addition of an inverter or two will allow expansion to even larger decoder networks.

Chip Select Decoder

Using a very similar circuit to the I/O port decoder, an array of 8205s can be used to create a simple interface to a 24K memory system.

The memory devices used can be either ROM or RAM and are 1K in storage capacity. 8308s and 8102s are the devices typically used for this application. This type of memory device has ten (10) address inputs and an active "low" chip select ($\overline{CS}$). The lower order address bits A0-A9 which come from the microprocessor are "bussed" to all memory elements and the chip select to enable a specific device or group of devices comes from the array of 8205s. The output of the 8205 is active low so it is directly compatible with the memory components.

Basic operation is that the CPU issues an address to identify a specific memory location in which it wishes to "write" or "read" data. The most significant address bits A10-A14 are decoded by the array of 8205s and an exclusive, active low, chip select is generated that enables a specific memory device. The least significant address bits A0-A9 identify a specific location within the selected device. Thus, all addresses throughout the entire memory array are exclusive in nature and are non-redundant.

This technique can be expanded almost indefinitely to support even larger systems with the addition of a few inverters and an extra decoder (8205).

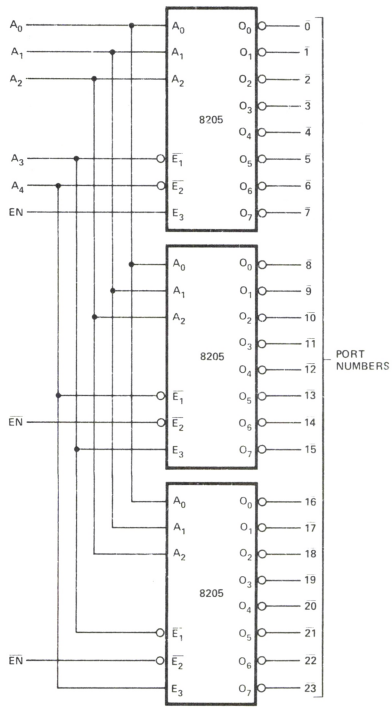


Figure 2. I/O Port Decoder

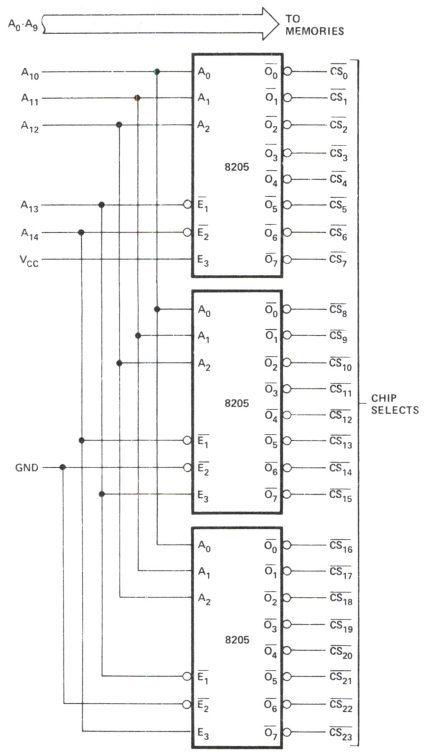


Figure 3. 32K Memory Interface

Logic Element Example

Probably the most overlooked application of the 8205 is that of a general purpose logic element. Using the "on-chip" enabling gate, the 8205 can be configured to gate its decoded outputs with system timing signals and generate strobes that can be directly connected to latches, flip-flops and one-shots that are used throughout the system.

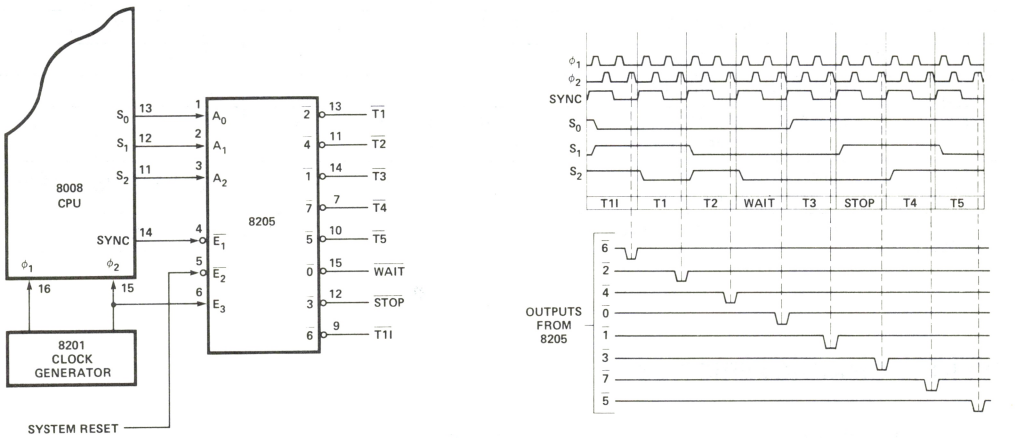
An excellent example of such an application is the "state decoder" in an 8008 CPU based system. The 8008 CPU issues three bits of information (S0, S1, S2) that indicate the nature of the data on the Data Bus during each machine state. Decoding of these signals is vital to generate strobes that can load the address latches, control bus discipline and general machine functions.

In the figure below a circuit is shown using the 8205 as the "state decoder" for an 8008 CPU that not only decodes the S0, S1, S2 outputs but gates these signals with the clock (phase 2) and the SYNC output of the 8008 CPU. The $\overline{T1}$ and $\overline{T2}$ decoded strobes can connect directly to devices like 8212s for latching the address information. The other decoded strobes can be used to generate signals to control the system data bus, memory timing functions and interrupt structure. RESET is connected to the enable gate so that strobes are not generated during system reset, eliminating accidental loading.

The power of such a circuit becomes evident when a single decoded strobe is logically broken down. Consider $\overline{T1}$ output, the boolean equation for it would be:

$$\overline{T1} = (\overline{S0} \cdot S1 \cdot \overline{S2}) \cdot (\overline{SYNC} \cdot \text{Phase 2} \cdot \overline{Reset})$$

A six input NAND gate plus a few inverters would be needed to implement this function. The seven remaining outputs would need a similar circuit to duplicate their function, obviously a substantial savings in components can be achieved when using such a technique.



State Control Coding

S_0	S_1	S_2	STATE
0	1	0	T1
0	1	1	T1I
0	0	1	T2
0	0	0	WAIT
1	0	0	T3
1	1	0	STOP
1	1	1	T4
1	0	1	T5

Figure 4. 8205 State Decoder Circuit

ABSOLUTE MAXIMUM RATINGS*

Temperature Under Bias:	Ceramic	−65°C to +125°C
	Plastic	−65°C to +75°C
Storage Temperature		−65°C to +160°C
All Output or Supply Voltages		−0.5 to +7 Volts
All Input Voltages		−1.0 to +5.5 Volts
Output Currents		125 mA

*COMMENT

Stresses above those listed under "Absolute Maximum Rating" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or at any other condition above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

D.C. CHARACTERISTICS

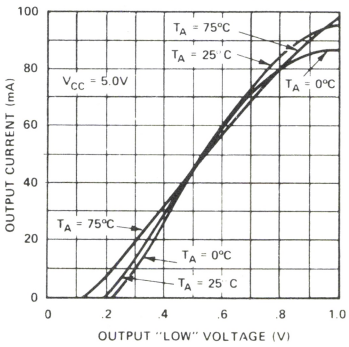
T_A = 0°C to +75°C, V_{CC} = 5V ±5%

8205

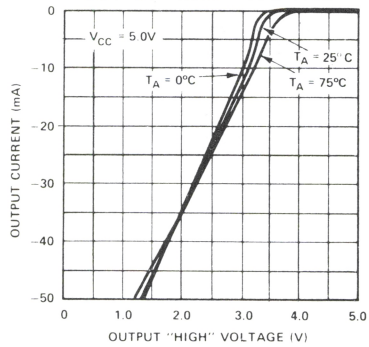
SYMBOL	PARAMETER	LIMIT MIN.	LIMIT MAX.	UNIT	TEST CONDITIONS
I_F	INPUT LOAD CURRENT		−0.25	mA	V_{CC} = 5.25V, V_F = 0.45V
I_R	INPUT LEAKAGE CURRENT		10	μA	V_{CC} = 5.25V, V_R = 5.25V
V_C	INPUT FORWARD CLAMP VOLTAGE		−1.0	V	V_{CC} = 4.75V, I_C = −5.0 mA
V_{OL}	OUTPUT "LOW" VOLTAGE		0.45	V	V_{CC} = 4.75V, I_{OL} = 10.0 mA
V_{OH}	OUTPUT HIGH VOLTAGE	2.4		V	V_{CC} = 4.75V, I_{OH} = −1.5 mA
V_{IL}	INPUT "LOW" VOLTAGE		0.85	V	V_{CC} = 5.0V
V_{IH}	INPUT "HIGH" VOLTAGE	2.0		V	V_{CC} = 5.0V
I_{SC}	OUTPUT HIGH SHORT CIRCUIT CURRENT	−40	−120	mA	V_{CC} = 5.0V, V_{OUT} = 0V
V_{OX}	OUTPUT "LOW" VOLTAGE @ HIGH CURRENT		0.8	V	V_{CC} = 5.0V, I_{OX} = 40 mA
I_{CC}	POWER SUPPLY CURRENT		70	mA	V_{CC} = 5.25V

TYPICAL CHARACTERISTICS

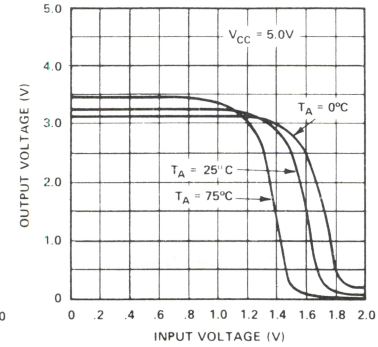
OUTPUT CURRENT VS. OUTPUT "LOW" VOLTAGE



OUTPUT CURRENT VS. OUTPUT "HIGH" VOLTAGE



DATA TRANSFER FUNCTION



SWITCHING CHARACTERISTICS

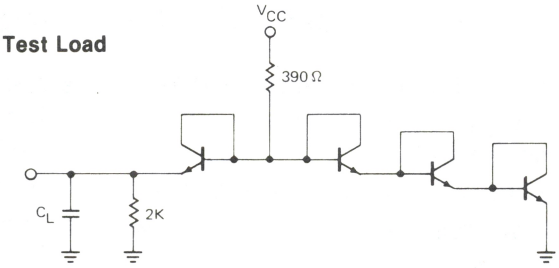
Conditions of Test:

Input pulse amplitudes: 2.5V

Input rise and fall times: 5 nsec between 1V and 2V

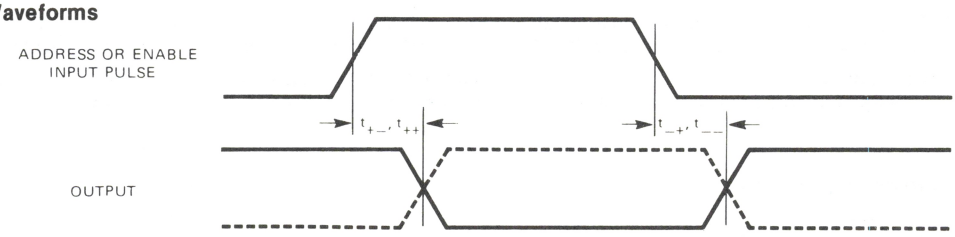
Measurements are made at 1.5V

Test Load



All Transistors 2N2369 or Equivalent. C_L = 30 pF

Test Waveforms



A.C. CHARACTRISTICS

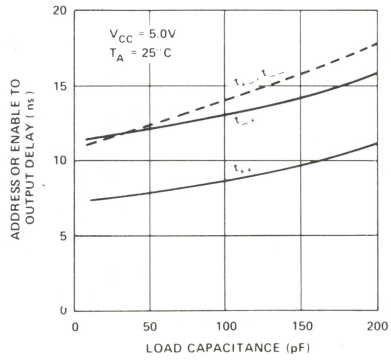
T_A = 0°C to +75°C, V_{CC} = 5V ±5% unless otherwise specified.

SYMBOL	PARAMETER		MAX. LIMIT	UNIT	TEST CONDITIONS
t_{++}	ADDRESS OR ENABLE TO OUTPUT DELAY		18	ns	
t_{-+}			18	ns	
t_{+-}			18	ns	
t_{--}			18	ns	
C_{IN} [1]	INPUT CAPACITANCE	P8205	4(typ.)	pF	f = 1 MHz, V_{CC} = 0V
		C8205	5(typ.)	pF	V_{BIAS} = 2.0V, T_A = 25°C

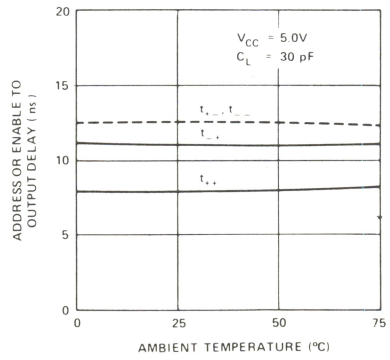
1. This parameter is periodically sampled and is not 100% tested.

TYPICAL CHARACTERISTICS

ADDRESS OR ENABLE TO OUTPUT DELAY VS. LOAD CAPACITANCE



ADDRESS OR ENABLE TO OUTPUT DELAY VS. AMBIENT TEMPERATURE



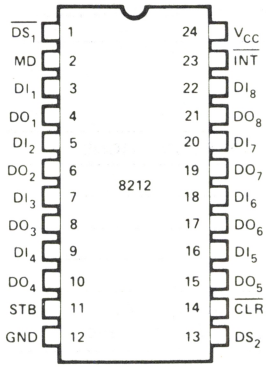
8212
8-BIT INPUT/OUTPUT PORT

- **Fully Parallel 8-Bit Data Register and Buffer**
- **Service Request Flip-Flop for Interrupt Generation**
- **Low Input Load Current — .25mA Max.**
- **Three State Outputs**
- **Outputs Sink 15mA**
- **3.65V Output High Voltage for Direct Interface to 8008, 8080A, or 8085A CPU**
- **Asynchronous Register Clear**
- **Replaces Buffers, Latches and Multiplexers in Microcomputer Systems**
- **Reduces System Package Count**

The 8212 input/output port consists of an 8-bit latch with 3-state output buffers along with control and device selection logic. Also included is a service request flip-flop for the generation and control of interrupts to the microprocessor.

The device is multimode in nature. It can be used to implement latches, gated buffers or multiplexers. Thus, all of the principal peripheral and input/output functions of a microcomputer system can be implemented with this device.

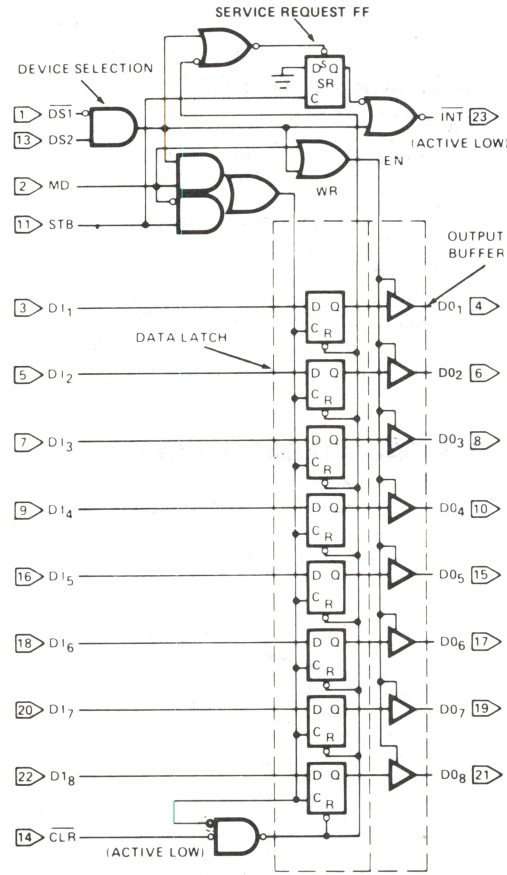
PIN CONFIGURATION



PIN NAMES

DI_1 DI_8	DATA IN
DO_1-DO_8	DATA OUT
$\overline{DS_1}$, DS_2	DEVICE SELECT
MD	MODE
STB	STROBE
$\overline{INT}$	INTERRUPT (ACTIVE LOW)
$\overline{CLR}$	CLEAR (ACTIVE LOW)

LOGIC DIAGRAM



FUNCTIONAL DESCRIPTION

Data Latch

The 8 flip-flops that make up the data latch are of a "D" type design. The output (Q) of the flip-flop will follow the data input (D) while the clock input (C) is high. Latching will occur when the clock (C) returns low.

The latched data is cleared by an asynchronous reset input ($\overline{CLR}$). (Note: Clock (C) Overrides Reset ($\overline{CLR}$).)

Output Buffer

The outputs of the data latch (Q) are connected to 3-state, non-inverting output buffers. These buffers have a common control line (EN); this control line either enables the buffer to transmit the data from the outputs of the data latch (Q) or disables the buffer, forcing the output into a high impedance state. (3-state)

The high-impedance state allows the designer to connect the 8212 directly onto the microprocessor bi-directional data bus.

Control Logic

The 8212 has control inputs $\overline{DS1}$, DS2, MD and STB. These inputs are used to control device selection, data latching, output buffer state and service request flip-flop.

$\overline{DS1}$, DS2 (Device Select)

These 2 inputs are used for device selection. When $\overline{DS1}$ is low and DS2 is high ($\overline{DS1} \cdot DS2$) the device is selected. In the selected state the output buffer is enabled and the service request flip-flop (SR) is asynchronously set.

MD (Mode)

This input is used to control the state of the output buffer and to determine the source of the clock input (C) to the data latch.

When MD is high (output mode) the output buffers are enabled and the source of clock (C) to the data latch is from the device selection logic ($\overline{DS1} \cdot DS2$).

When MD is low (input mode) the output buffer state is determined by the device selection logic ($\overline{DS1} \cdot DS2$) and the source of clock (C) to the data latch is the STB (Strobe) input.

STB (Strobe)

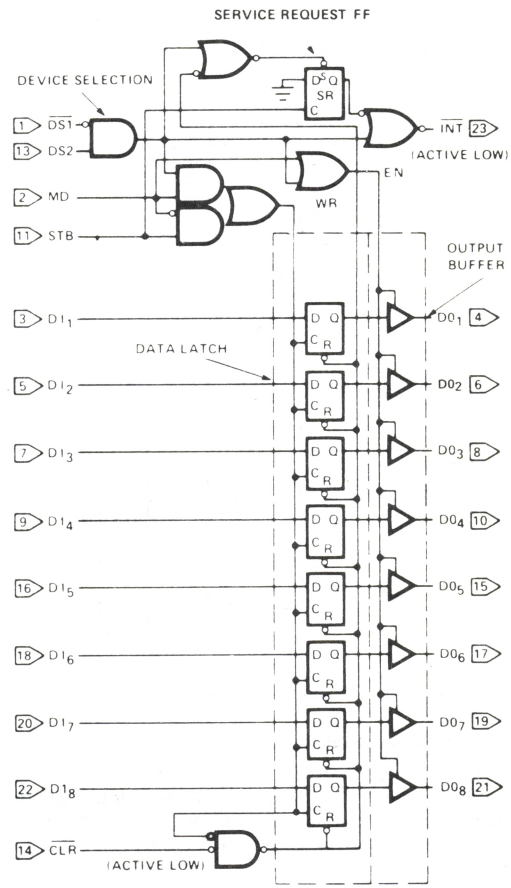
This input is used as the clock (C) to the data latch for the input mode MD = 0) and to synchronously reset the service request flip-flop (SR).

Note that the SR flip-flop is negative edge triggered.

Service Request Flip-Flop

The (SR) flip-flop is used to generate and control interrupts in microcomputer systems. It is asynchronously set by the $\overline{CLR}$ input (active low). When the (SR) flip-flop is set it is in the non-interrupting state.

The output of the (SR) flip-flop (Q) is connected to an inverting input of a "NOR" gate. The other input to the "NOR" gate is non-inverting and is connected to the device selection logic ($\overline{DS1} \cdot DS2$). The output of the "NOR" gate ($\overline{INT}$) is active low (interrupting state) for connection to active low input priority generating circuits.



STB	MD	(DS_1 DS_2)	DATA OUT EQUALS
0	0	0	3-STATE
1	0	0	3-STATE
0	1	0	DATA LATCH
1	1	0	DATA LATCH
0	0	1	DATA LATCH
1	0	1	DATA IN
0	1	1	DATA IN
1	1	1	DATA IN

CLR	($\overline{DS_1}$ DS_2)	STB	*SR	INT
0	0	0	1	1
0	1	0	1	0
1	1	⌐	0	0
1	1	0	1	0
1	0	0	1	1
1	1	⌐	1	0

*INTERNAL SR FLIP-FLOP

$\overline{CLR}$ – RESETS DATA LATCH
SETS SR FLIP-FLOP
(NO EFFECT ON OUTPUT BUFFER)

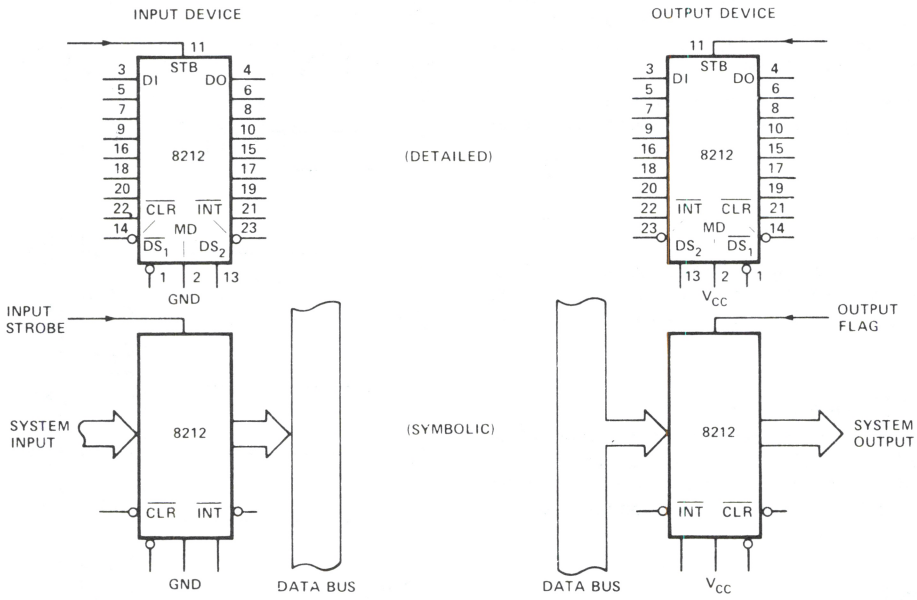
Applications of the 8212 — For Microcomputer Systems

I Basic Schematic Symbol
II Gated Buffer
III Bi-Directional Bus Driver
IV Interrupting Input Port
V Interrupt Instruction Port
VI Output Port
VII 8080A Status Latch
VIII 8085A Address Latch

1. Basic Schematic Symbols

Two examples of ways to draw the 8212 on system schematics — (1) the top being the detailed view showing pin numbers, and (2) the bottom being the symbolic view showing the system input or output as a system bus (bus containing 8 parallel lines). The output to the data bus is symbolic in referencing 8 parallel lines.

BASIC SCHEMATIC SYMBOLS



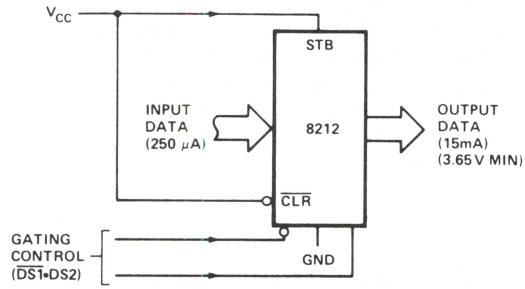
II. Gated Buffer (3-State)

The simplest use of the 8212 is that of a gated buffer. By tying the mode signal low and the strobe input high, the data latch is acting as a straight through gate. The output buffers are then enabled from the device selection logic $\overline{DS1}$ and DS2.

When the device selection logic is false, the outputs are 3-state.

When the device selection logic is true, the input data from the system is directly transferred to the output. The input data load is 250 micro amps. The output data can sink 15 milli amps. The minimum high output is 3.65 volts.

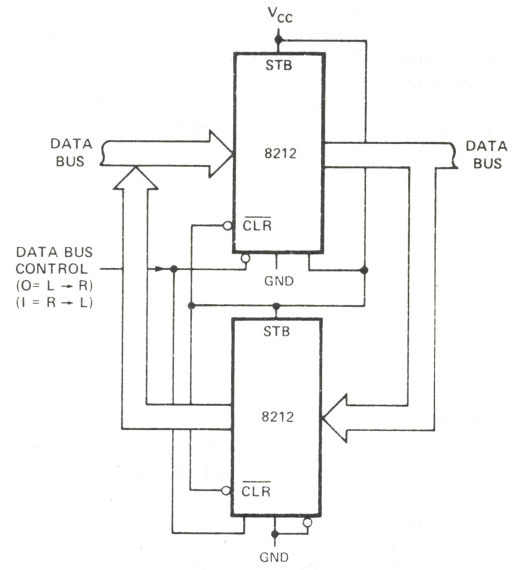
GATED BUFFER



III. Bi-Directional Bus Driver

A pair of 8212's wired (back-to-back) can be used as a symmetrical drive, bi-directional bus driver. The devices are controlled by the data bus input control which is connected to $\overline{DS1}$ on the first 8212 and to DS2 on the second. One device is active, and acting as a straight through buffer the other is in 3-state mode. This is a very useful circuit in small system design.

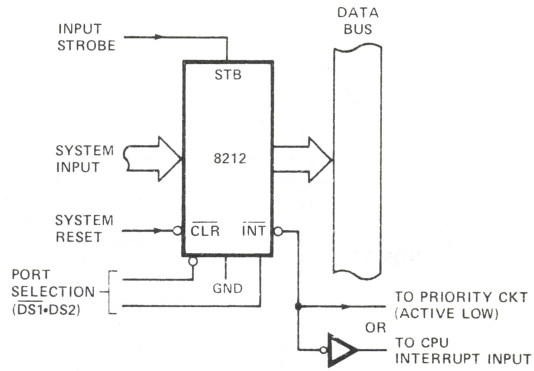
BI-DIRECTIONAL BUS DRIVER



IV. Interrupting Input Port

This use of an 8212 is that of a system input port that accepts a strobe from the system input source, which in turn clears the service request flip-flop and interrupts the processor. The processor then goes through a service routine, identifies the port, and causes the device selection logic to go true — enabling the system input data onto the data bus.

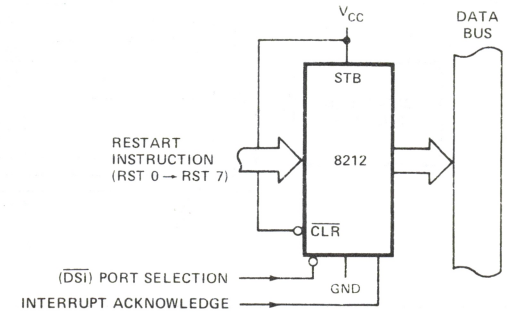
INTERRUPTING INPUT PORT



V. Interrupt Instruction Port

The 8212 can be used to gate the interrupt instruction, normally RESTART instructions, onto the data bus. The device is enabled from the interrupt acknowledge signal from the microprocessor and from a port selection signal. This signal is normally tied to ground. ($\overline{DS1}$ could be used to multiplex a variety of interrupt instruction ports onto a common bus).

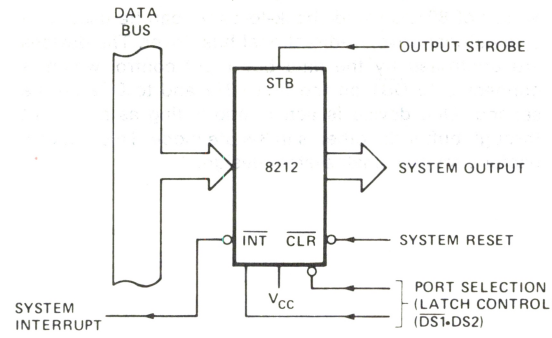
INTERRUPT INSTRUCTION PORT



VI. Output Port (With Hand-Shaking)

The 8212 can be used to transmit data from the data bus to a system output. The output strobe could be a hand-shaking signal such as "reception of data" from the device that the system is outputting to. It in turn, can interrupt the system signifying the reception of data. The selection of the port comes from the device selection logic.($\overline{DS1} \cdot DS2$)

OUTPUT PORT (WITH HAND-SHAKING)

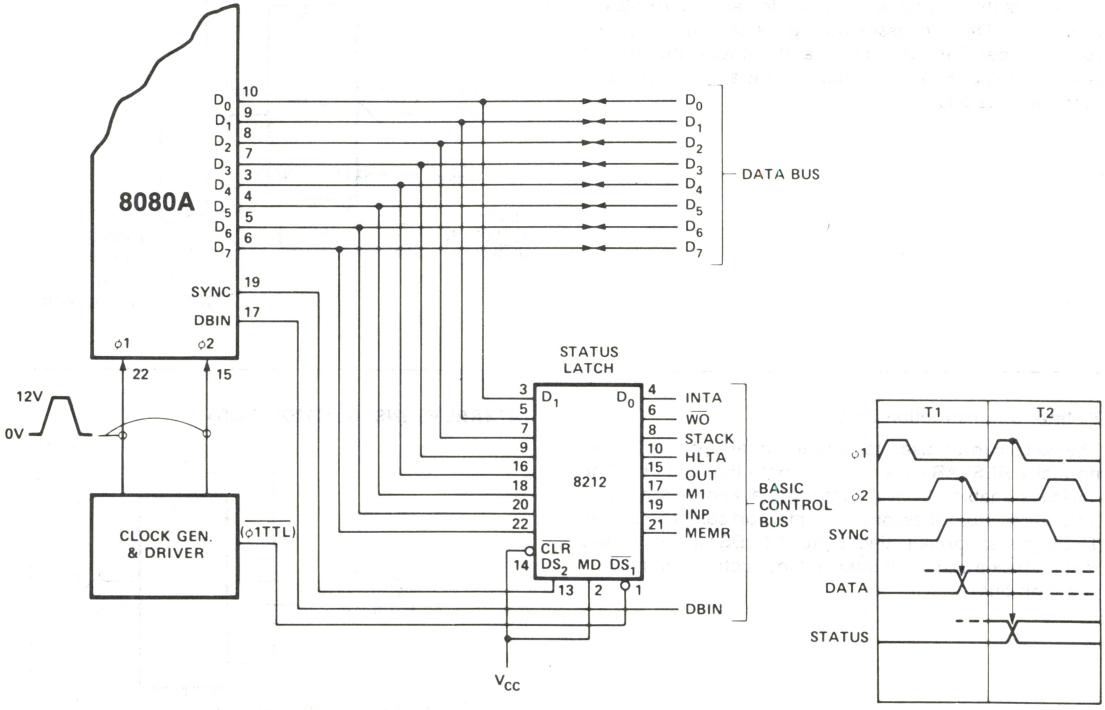


VII. 8080A Status Latch

Here the 8212 is used as the status latch for an 8080A microcomputer system. The input to the 8212 latch is directly from the 8080A data bus. Timing shows that when the SYNC signal is true, which is connected to the DS2 input and the phase 1 signal is true, which is a TTL level coming from the clock generator; then, the status data will be latched into the 8212.

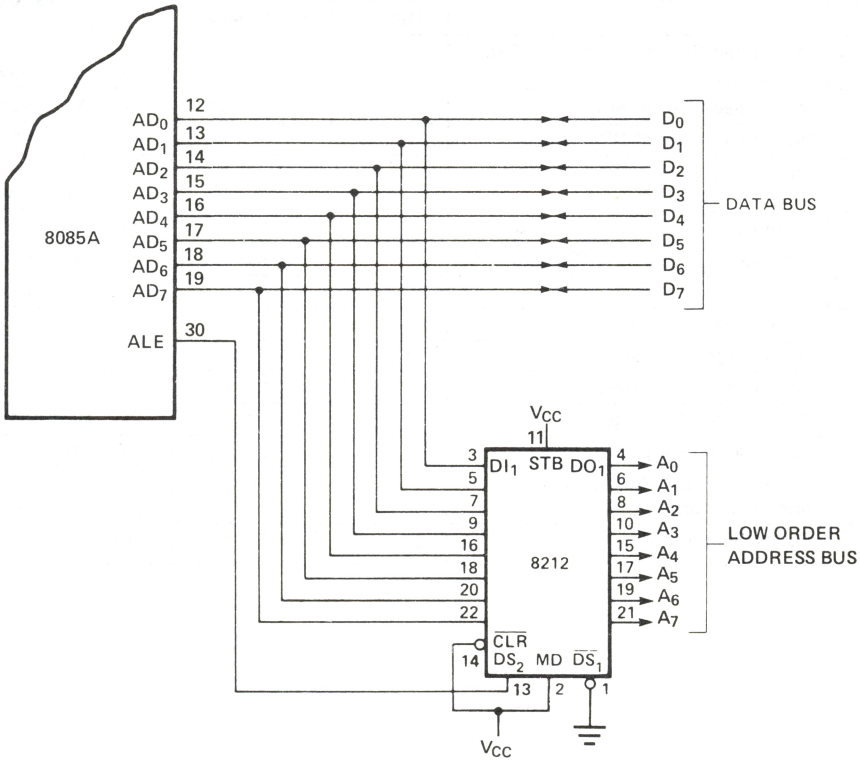
Note: The mode signal is tied high so that the output on the latch is active and enabled all the time.

It is shown that the two areas of concern are the bi-directional data bus of the microprocessor and the control bus.



VIII. 8085A Low-Order Address Latch

The 8085A microprocessor uses a multiplexed address/data bus that contains the low order 8-bits of address information during the first part of a machine cycle. The same bus contains data at a later time in the cycle. An address latch enable (ALE) signal is provided by the 8085A to be used by the 8212 to latch the address so that it may be available through the whole machine cycle. Note: In this configuration, the MODE input is tied high, keeping the 8212's output buffers turned on at all times.



ABSOLUTE MAXIMUM RATINGS*

Temperature Under Bias Plastic ..... 0°C to +70°C
Storage Temperature ..... -65°C to +160°C
All Output or Supply Voltages ..... -0.5 to +7 Volts
All Input Voltages ..... -1.0 to 5.5 Volts
Output Currents 100mA

*COMMENT

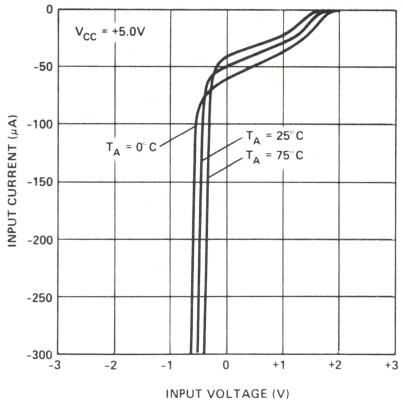
Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

D.C. CHARACTERISTICS $T_A = 0°C$ to $+75°C$, $V_{CC} = +5V \pm 5\%$

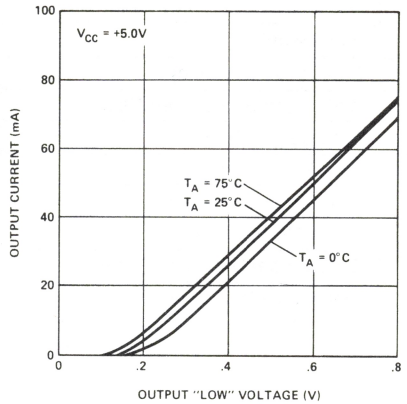
Symbol	Parameter	Limits			Unit	Test Conditions
		Min.	Typ.	Max.		
I_F	Input Load Current, ACK, DS_2, CR, DI_1-DI_8 Inputs			-.25	mA	$V_F = .45V$
I_F	Input Load Current MD Input			-.75	mA	$V_F = .45V$
I_F	Input Load Current DS_1 Input			-1.0	mA	$V_F = .45V$
I_R	Input Leakage Current, ACK, DS, CR, DI_1-DI_8 Inputs			10	μA	$V_R \leq V_{CC}$
I_R	Input Leakage Current MO Input			30	μA	$V_R \leq V_{CC}$
I_R	Input Leakage Current DS_1 Input			40	μA	$V_R \leq V_{CC}$
V_C	Input Forward Voltage Clamp			-1	V	$I_C = -5mA$
V_{IL}	Input "Low" Voltage			.85	V	
V_{IH}	Input "High" Voltage	2.0			V	
V_{OL}	Output "Low" Voltage			.45	V	$I_{OL} = 15mA$
V_{OH}	Output "High" Voltage	3.65	4.0		V	$I_{OH} = -1mA$
I_{SC}	Short Circuit Output Current	-15		-75	mA	$V_O = 0V$, $V_{CC} = 5V$
$\|I_O\|$	Output Leakage Current High Impedance State			20	μA	$V_O = .45V/5.25V$
I_{CC}	Power Supply Current		90	130	mA	

TYPICAL CHARACTERISTICS

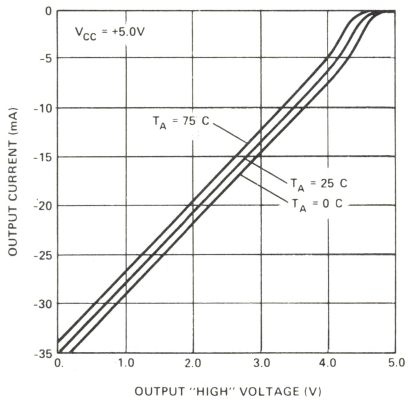
INPUT CURRENT VS. INPUT VOLTAGE



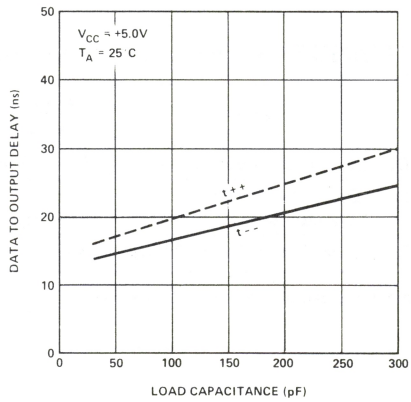
OUTPUT CURRENT VS. OUTPUT "LOW" VOLTAGE



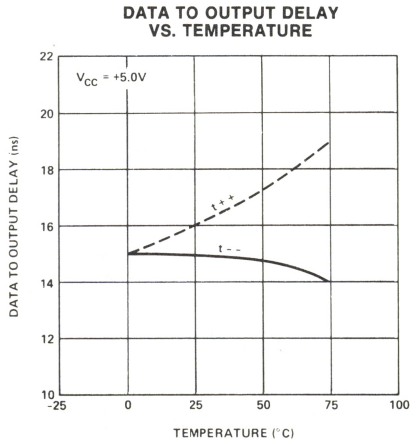
OUTPUT CURRENT VS. OUTPUT "HIGH" VOLTAGE



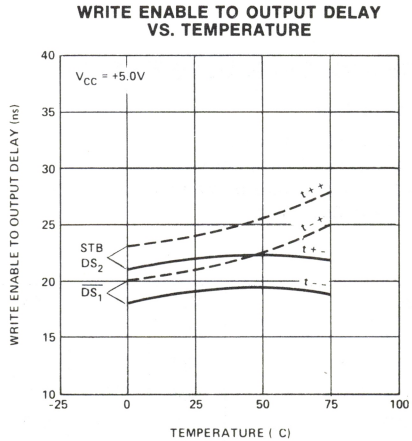
DATA TO OUTPUT DELAY VS. LOAD CAPACITANCE



DATA TO OUTPUT DELAY VS. TEMPERATURE



WRITE ENABLE TO OUTPUT DELAY VS. TEMPERATURE



A.C. CHARACTERISTICS $T_A = 0°C$ to $+70°C$, $V_{CC} = +5V \pm 5\%$

Symbol	Parameter	Limits			Unit	Test Conditions
		Min.	Typ.	Max.		
t_{PW}	Pulse Width	30			ns	
t_{PD}	Data to Output Delay			30	ns	Note 1
t_{WE}	Write Enable to Output Delay			40	ns	Note 1
t_{SET}	Data Set Up Time	15			ns	
t_H	Data Hold Time	20			ns	
t_R	Reset to Output Delay			40	ns	Note 1
t_S	Set to Output Delay			30	ns	Note 1
t_E	Output Enable/Disable Time			45	ns	Note 1
t_C	Clear to Output Delay			55	ns	Note 1

CAPACITANCE* $F = 1MHz$, $V_{BIAS} = 2.5V$, $V_{CC} = +5V$, $T_A = 25°C$

Symbol	Test	Limits	
		Typ.	Max.
C_{IN}	DS_1 MD Input Capacitance	9pF	12pF
C_{IN}	DS_2, CK, ACK, DI_1-DI_8 Input Capacitance	5pF	9pF
C_{OUT}	DO_1-DO_8 Output Capacitance	8pF	12pF

*This parameter is sampled and not 100% tested.

SWITCHING CHARACTERISTICS

Conditions of Test

Input Pulse Amplitude = 2.5V
Input Rise and Fall Times 5ns
Between 1V and 2V Measurements made at 1.5V
with 15mA and 30pF Test Load

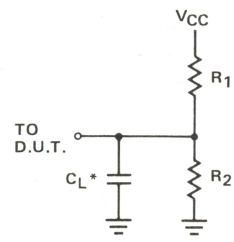
Note 1:

Test	C_L*	R_1	R_2
t_{PD}, t_{WE}, t_R, t_S, t_C	30pF	300Ω	600Ω
t_E, ENABLE↑	30pF	10KΩ	1KΩ
t_E, ENABLE ↓	30pF	300Ω	600Ω
t_E, DISABLE↑	5pF	300Ω	600Ω
t_E, DISABLE↓	5pF	10KΩ	1KΩ

*Includes probe and jig capacitance.

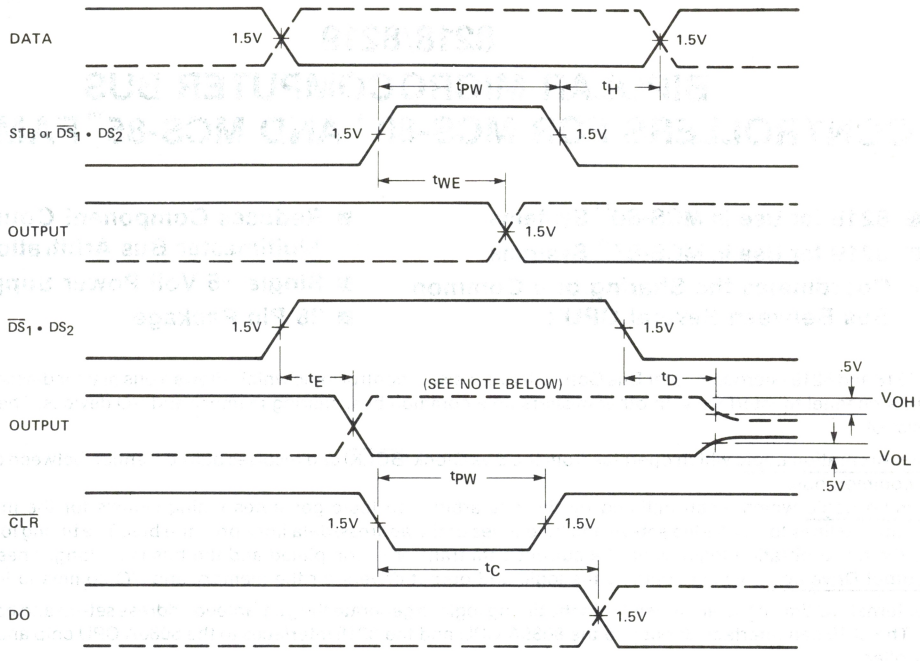
Test Load

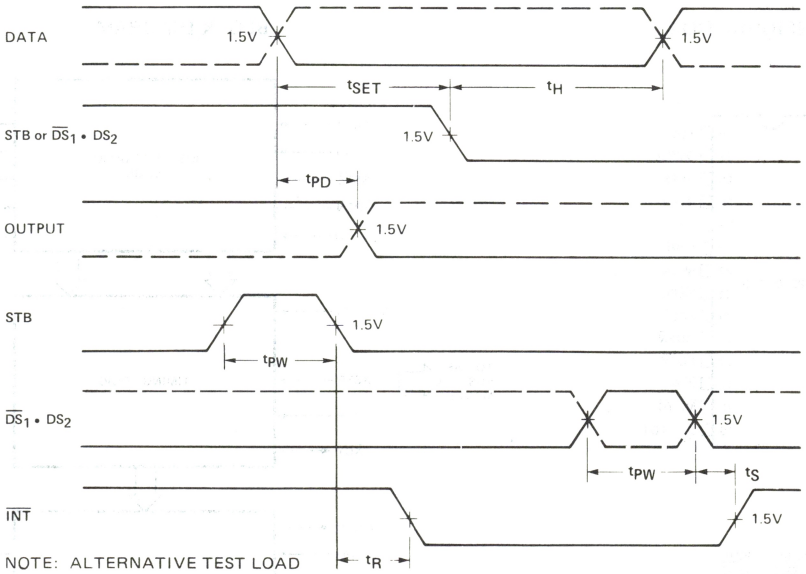
15mA & 30pF



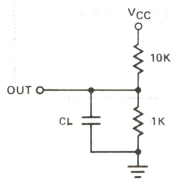
*INCLUDING JIG & PROBE CAPACITANCE

TIMING DIAGRAM





NOTE: ALTERNATIVE TEST LOAD



PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

8218/8219
BIPOLAR MICROCOMPUTER BUS CONTROLLERS FOR MCS-80™ AND MCS-85™ FAMILIES

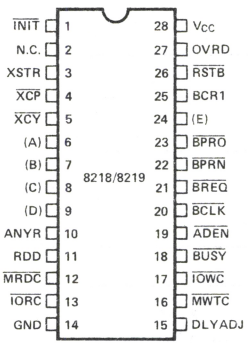
- **8218 for Use in MCS-80™ Systems**
- **8219 for Use in MCS-85™ Systems**
- **Coordinates the Sharing of a Common Bus Between Several CPU's**
- **Reduces Component Count in Multimaster Bus Arbitration Logic**
- **Single +5 Volt Power Supply**
- **28 Pin Package**

The 8218 and 8219 Microcomputer Bus Controllers consist of control logic which allows a bus master device such as a CPU or DMA channel to interface with other masters on a common bus, sharing memory and I/O devices. The 8218 and 8219 consist of:

1. Bus Arbitration Logic which operates from the Bus Clock ($\overline{BCLK}$) and resolves bus contention between devices sharing a common bus.
2. Timing Logic which when initiated by the bus arbitration logic generates timing signals for the memory and I/O command lines to guarantee set-up and hold times of the address/data lines onto the bus. The timing logic also signals to the bus arbitration logic when the current data transfer is completed and the bus is no longer needed.
3. Output Drive Logic which contains the logic and output drivers for the memory and I/O command lines.

An external RC time constant is used with the timing logic to generate the guaranteed address set-up and hold times on the bus. The 8219 can interface directly to the 8085A CPU and the 8218 interfaces to the 8080A CPU chip and the 8257 DMA controller.

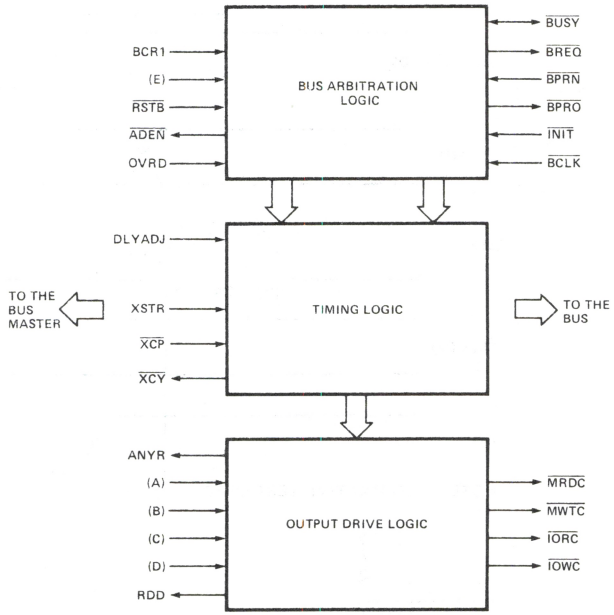
PIN CONFIGURATION



	8218	8219
(A)	$\overline{IOWR}$	IO/$\overline{M}$
(B)	$\overline{MWTR}$	$\overline{WR}$
(C)	$\overline{IORR}$	$\overline{RD}$
(D)	$\overline{MRDR}$	$\overline{ASRQ}$
(E)	$\overline{BCR2}$	BCR2

N.C. = NO CONNECT

BLOCK DIAGRAM



PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

8218/8219 PIN DEFINITIONS

Signals Interfaced Directly to the System Bus

$\overline{\text{BREQ}}$ (TTL Output)

The Bus-Request is used with a central parallel priority resolution circuit. It indicates that the device needs to access the bus for one or more data transfers. It is synchronized with the Bus Clock.

$\overline{\text{BUSY}}$ (Input, O.C. Output)

Bus-Busy indicates to all master devices on the bus that the bus is in use. It inhibits any other device from getting the bus. It is synchronized with Bus Clock.

$\overline{\text{BCLK}}$ (Input)

The negative edge of Bus-Clock is used to synchronize the bus contention resolution circuit asynchronously to the CPU clock. It has 100ns min. period, 35%-65% duty cycle. It may be slowed, single stepped or stopped.

$\overline{\text{BPRN}}$ (Input)

The Bus-Priority-In indicates to a device that no device of a higher priority is requesting the bus. It is synchronous with the Bus Clock.

$\overline{\text{BPRO}}$ (TTL Output)

The Bus-Priority-Out is used with serial priority resolution circuits. Priority may be transferred to the next lower in priority as $\overline{\text{BPRN}}$.

$\overline{\text{INIT}}$ (Input)

The Initialize resets the 8218/8219 to a known internal state.

$\overline{\text{MRDC}}$ (3-State Output)

The Memory-Read-Control indicates that the Master is requesting a read operation from the addressed location. It is asynchronous to the Bus Clock.

$\overline{\text{MWTC}}$ (3-State Output)

The Memory-Write-Control indicates that data and an address have been placed on the bus by the Master and the data is to be deposited at that location. It is asynchronous to the Bus Clock.

$\overline{\text{IORC}}$ (3-State Output)

The I/O-Read-Control indicates that the Master is requesting a read operation from the I/O device addressed. It is asynchronous to the Bus Clock.

$\overline{\text{IOWC}}$ (3-State Output)

The I/O-Write-Control indicates that Data and an I/O device address has been placed on the bus by the Master and the data is to be deposited to the I/O device.

Signals Generated or Received by the Bus Master

BCR1/$\overline{\text{BCR2}}$ (Inputs)

Bus-Control-Request 1 or Bus-Control-Request 2 indicate to the 8218/8219 that the Master device is making a request to control the bus. BCR2 is active low in the 8218 ($\overline{\text{BCR2}}$). BCR2 is active high in the 8219.

RSTB (Input)

Request-Strobe latches the status of BCR1 and BCR2 into the 8218/8219. The strobe is active low in the 8218 and negative edge triggered in the 8219.

$\overline{\text{ADEN}}$ (TTL Output)

Address-and-Data-Enable indicates the Master has control of the bus. It is often used to enable Address and Data Buffers on the bus. It is synchronous with Bus Clock.

RDD (TTL Output)

Read-Data controls the direction of the bi-directional data bus drivers. It is asynchronous to the Bus Clock. A high on RDD indicates a read mode by the master.

OVRD (Input)

Override inhibits automatic deselect between transfers caused by a higher priority bus request. May be used for consecutive data transfers such as read-modify-write operations. It is asynchronous to the Bus Clock.

XSTR (Input, Rising-Edge-Triggered)

Transfer-Start-Request indicates to the 8218/8219 that a new data transfer cycle is requested to start. It is raised for each new word transfer in a multiple data word transfer. It is asynchronous to the Bus Clock.

$\overline{\text{XCP}}$ (Input, Falling-Edge-Triggered)

Transfer-Complete indicates to the 8218/8219 that the data has been received by the slave device in a write cycle or transmitted by the slave and received by master in a read cycle. It is asynchronous to the Bus Clock.

$\overline{\text{XCY}}$ (TTL Output)

Indicates that a data transfer is in progress. It is asynchronous to the Bus Clock.

$\overline{\text{WR}}$, $\overline{\text{RD}}$, IO/$\overline{\text{M}}$ (8219 Only) (Inputs from 8085 to the 8219)

WRITE, READ, IO/$\overline{\text{Memory}}$ are the control request inputs used by the 8085 and are internally decoded by the 8219 to produce the request signals $\overline{\text{MRDR}}$, $\overline{\text{MWTR}}$, $\overline{\text{IORR}}$, $\overline{\text{IOWR}}$. They are asynchronous to the Bus Clock.

$\overline{\text{ASRQ}}$ (8219 Only) (Input from 8085 System)

Can be used for interrupt status from the 8085. Acts like a level sensitive asynchronous bus request — no RSTB needed. It is asynchronous to the Bus Clock.

$\overline{\text{MRDR}}$, $\overline{\text{MWTR}}$, $\overline{\text{IORR}}$, $\overline{\text{IOWR}}$ (8218 Only) (Inputs from 8080 or 8257 to the 8218)

Memory-Read-Request, Memory-Write-Request, I/O-Read-Request, or I/O-Write-Request indicate that address and data have been placed on the bus and the appropriate request is being made to the addressed device. Only one of these inputs should be active at any one time. They are asynchronous to the Bus Clock.

ANYR (TTL Output)

Any-Request is the logical OR of the active state of $\overline{\text{MRDR}}$, $\overline{\text{MWTR}}$, $\overline{\text{IORR}}$, $\overline{\text{IOWR}}$. It may be tied to XSTR when the rising edge of ANYR is used to initiate a transfer.

PRELIMINARY
Notice: This is not a final specification. Some parameter limits are subject to change.

DLYADJ (Input)

Delay-Adjust is used for connection of an external capacitor and resistor to ground to adjust the required set-up and hold time of address to control signal.

8218/8219 FUNCTIONAL DESCRIPTION

The 8218/8219 is a bipolar Bus Control Chip which reduces component count in the interface between a master device and the system Bus. (Master device: 8080, 8085, 8257 (DMA).)

The 8218 and 8219 serve three major functions:

1. Resolve bus contention.
2. Guarantee set-up and hold time of address/data lines to I/O and Memory read/write control signals (adjustable by external capacitor).
3. Provide sufficient drive on all bus command lines.

Bus Arbitration Logic

Bus Arbitration Logic activity begins when the Master makes a request for use of the bus on BCR1 or $\overline{BCR2}$. The request is strobed in by $\overline{RSTB}$. Following the next two falling edges of the bus clock (BCLK) the 8218/8219 outputs a bus request ($\overline{BREQ}$) and forces Bus Priority Out inactive (BPRO). See Figures 1a and 1b.

$\overline{BREQ}$ is used for requesting the bus when priority is decided by a parallel priority resolver circuit.

$\overline{BPRO}$ is used to allow lower priority devices to gain the bus when a serial priority resolving structure is used. $\overline{BPRO}$ would go to $\overline{BPRN}$ of the next lower priority Master.

When priority is granted to the Master (a low on $\overline{BPRN}$ and a high on $\overline{BUSY}$) the Master outputs a $\overline{BUSY}$ signal on the next falling edge of $\overline{BCLK}$. The $\overline{BUSY}$ signal locks the master onto the bus and prohibits the enable of any other masters onto the bus.

At the same time $\overline{BUSY}$ goes active, Address and Data Enable ($\overline{ADEN}$) goes active signifying that the Master has control of the bus. $\overline{ADEN}$ is often used to enable the bus drivers.

The Bus will be released only if the master loses priority; is not in the middle of a transfer, and Override is not active or, if the Master stops requesting the bus, is not in the middle of a data transfer, and Override is not active. $\overline{ADEN}$ then goes inactive.

Provision has been made in the 8218 to allow bus-synchronous requests. This mode is activated when BCR1, $\overline{BCR2}$ and $\overline{RSTB}$ are all low. This action asynchronously sets the synchronization flip flop (FF2) in Figure 1a.

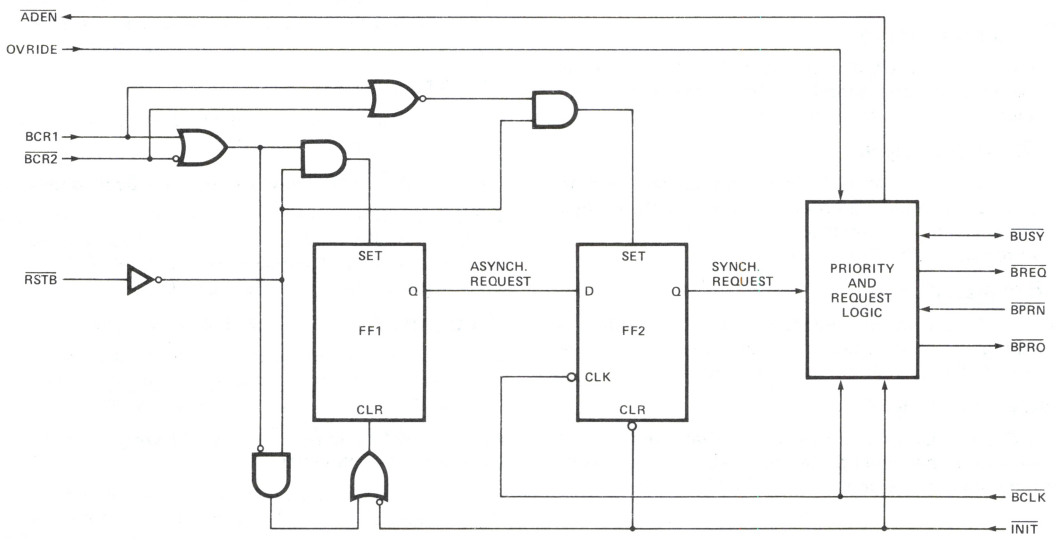


FIGURE 1a. 8218 BUS ARBITRATION LOGIC

PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

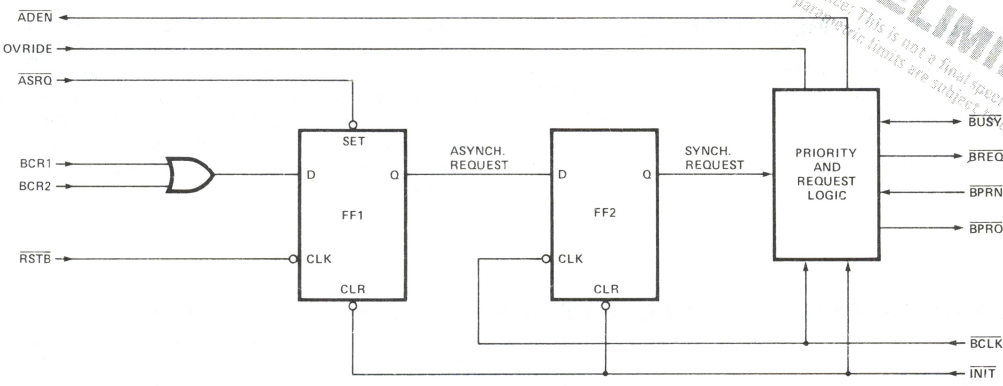


FIGURE 1b. 8219 BUS ARBITRATION LOGIC

Timing Logic

Timing Logic activity begins with the rising edge of XSTR (Transfer Start Request) or with $\overline{ADEN}$ going active, whichever occurs second. This action causes $\overline{XCY}$ (Transfer Cycle) to go active. 50-200ns later (depending on resistance and capacitance at DLYADJ) the appropriate Control Outputs will go active if the control input is active.

XSTR can be raised after the command goes active in the current transfer cycle so that a new transfer can be initiated immediately after the current transfer is complete.

A negative going edge on $\overline{XCP}$ (Transfer Complete) will cause the Control Outputs ($\overline{MRDC}$, etc.) to go inactive. 50-200ns later (depending on capacitance at DLYADJ) $\overline{XCY}$ will go inactive indicating the transfer cycle is completed.

Additional logic within the 8218/8219 guarantees that if a transfer cycle is started ($\overline{XCY}$ is active), but the bus is not requested ($\overline{BREQ}$ is inactive) and there is no command request input (ANYR is output low), then the transfer cycle will be cleared. This allows the bus to be released in applications where advanced bus requests are generated but the processor enters a HALT mode.

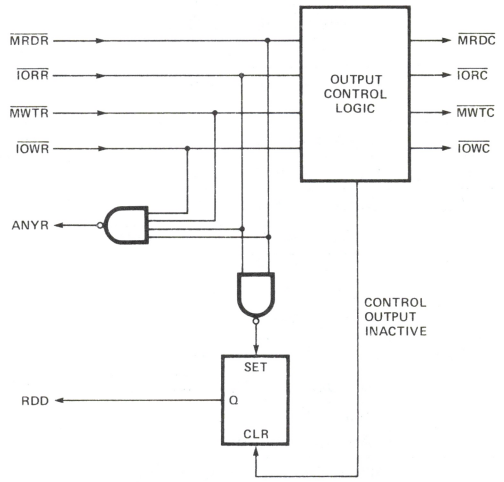


FIGURE 2a. 8218 CONTROL LOGIC

Control Logic

The control outputs are generated in the 8219 by decoding the 8085 system control outputs (i.e., RD, WR, IO/M) or in the 8218 by directly buffering the control inputs to the control outputs for use in an 8080 or DMA system (see Figures 2a and 2b). The control outputs may be held high (inactive) by the Timing Logic. Also the control outputs are enabled when the Master gains control of the bus and disabled when control is relinquished.

The Control Logic also has two other outputs, ANYR (Any Request) and RDD (Read Data). ANYR goes high (active) if any control requests (IOWR, etc.) are active. RDD controls the direction of the Masters Bi-directional Data Bus Drivers. The Bus Driver will always be in the Write mode (RDD = Low) except from the start of a Read Control Request to 25 to 70ns after $\overline{XCP}$ is activated.

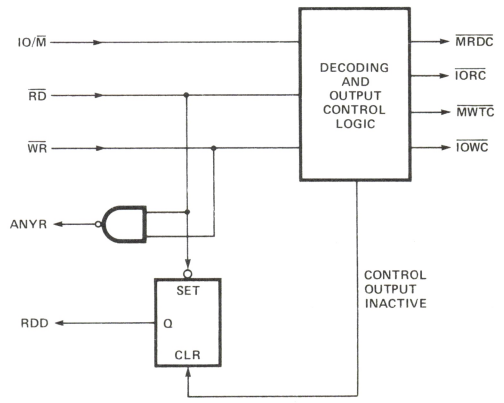


FIGURE 2b. 8219 CONTROL LOGIC

PRELIMINARY

ABSOLUTE MAXIMUM RATINGS*

Ambient Temperature Under Bias ..... 0°C to 70°C
Storage Temperature ..... -65°C to +150°C
Supply Voltage (V_{CC}) ..... -0.5V to +7V
Input Voltage ..... -1.0V to V_{CC} + 0.25V
Output Current 100mA

**COMMENT: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

D.C. AND OPERATING CHARACTERISTICS T_A = 0°C to 70°C; V_{CC} = 5V ± 5%

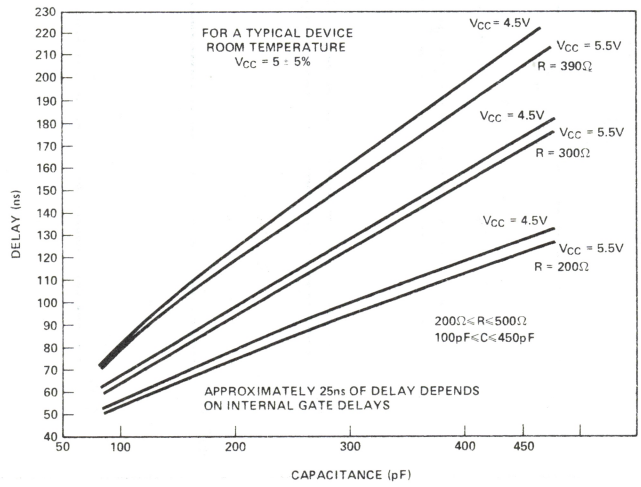
Symbol	Parameter	Limits			Unit	Test Conditions
		Min.	Typ.	Max.		
V_C	Input Clamp Voltage			-1.0	V	V_{CC} = 4.75V, I_C = -5mA
I_F	Input Load Current					
	$\overline{MRDR}$/$\overline{INTA}$/$\overline{MWTR}$/$\overline{WR}$					V_{CC} = 5.25V
	$\overline{IORR}$/$\overline{RD}$, IOWR/IO/$\overline{M}$			-0.5	mA	V_F = 0.45V
	Other			-0.5	mA	
I_R	Input Leakage Current			100	µA	V_{CC} = 5.25 V_R = 5.25
V_{TH}	Input Threshold Voltage	0.8		2.0	V	V_{CC} = 5V
I_{CC}	Power Supply Current		200	240	mA	V_{CC} = 5.25V
V_{OL}	Output Low Voltage					V_{CC} = 4.75
	$\overline{MRDC}$, $\overline{MWTC}$, $\overline{IORC}$, $\overline{IOWC}$			0.45	V	I_{OL} = 32mA
	$\overline{BREQ}$, $\overline{BUSY}$			0.45	V	I_{OL} = 20mA
	$\overline{XCY}$, $\overline{RDD}$, $\overline{ADEN}$			0.45	V	I_{OL} = 16mA
	$\overline{BPRO}$, ANYR			0.45	V	I_{OL} = 3.2mA
V_{OH}	Output High Voltage					V_{CC} = 4.75V
	$\overline{MRDC}$, $\overline{MWTC}$, $\overline{IORC}$, $\overline{IOWC}$ $\overline{BUSY}$ O.C.	2.4				I_{OH} = -2mA
	All Other Outputs	2.4				I_{OH} = -400µA
I_{OS}	Short Circuit Output Current	-10		-90	mA	V_{CC} = 5.25V, V_O = 0V
$I_{O(OFF)}$	Tri-State Output Current			-100	µA	V_{CC} = 5.25V, V_O = 0.45V
				+100	µA	V_{CC} = 5.25V, V_O = 5.25V

PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

A.C. CHARACTERISTICS $T_A = 0°C$ to $70°C$; $V_{CC} = 5V \pm 5\%$

Symbol	Parameter	Limits			Unit	Test Conditions
		Min.	Typ.	Max.		
t_{BCY}	Bus Clock Cycle Time	100			ns	35% to 65% Duty Cycle
t_{PW}	Bus Clock Pulse Width	35		0.65 t_{BCY}	ns	
t_{RQS}	$\overline{RSTB}$ to $\overline{BCLK}$ Set-Up Time	25			ns	
t_{CSS}	BCR_1 and $\overline{BCR_2}$ to $\overline{RSTB}$ Set-Up Time	15			ns	
t_{CSH}	BCR_1 and $\overline{BCR_2}$ to $\overline{RSTB}$ Hold Time	15			ns	
t_{RQD}	$\overline{BCLK}$ to $\overline{BREQ}$ Delay			35	ns	
t_{PRNS}	$\overline{BPRN}$ to $\overline{BCLK}$ Set-Up Time	23			ns	
t_{BNO}	$\overline{BRPN}$ to $\overline{BPRO}$ Delay			30	ns	
t_{BYD}	$\overline{BCLK}$ to $\overline{BUSY}$ Delay			55	ns	
t_{CAD}	$\overline{MRDR}$, $\overline{MWTR}$, $\overline{IORR}$, $\overline{IOWR}$ to ANYR Delay			30	ns	
t_{SXD}	XSTR to $\overline{XCY}$ Delay			40	ns	
t_{SCD}	XSTR to $\overline{MRDC}$, $\overline{MWTC}$, $\overline{IORC}$, $\overline{IOWC}$ Delay	50		200	ns	Adjustable by External R/C
t_{XSW}	XSTR Pulse Width	30			ns	
t_{XCD}	$\overline{XCP}$ to $\overline{MRDC}$, $\overline{MWTC}$, $\overline{IORC}$, $\overline{IOWC}$ Delay			50	ns	
t_{XCW}	$\overline{XCP}$ Pulse Width	35			ns	
t_{CCD}	$\overline{XCP}$ to $\overline{XCY}$ Delay	50		200	ns	Adjustable by External R/C
t_{CMD}	$\overline{MRDR}$, $\overline{MWTR}$, $\overline{IORR}$, $\overline{IOWR}$ to $\overline{MRDC}$, $\overline{MWTC}$, $\overline{IORC}$, $\overline{IOWC}$			35	ns	
t_{CRD}	$\overline{MRDR}$, $\overline{MWTR}$, $\overline{IORR}$, $\overline{IOWR}$ to RDD Delay			25	ns	
t_{RW}	$\overline{RSTB}$ Min. Neg. Pulse Width	30			ns	
t_{CPD}	$\overline{BCLK}$ to $\overline{BPRO}$ Delay			40	ns	
t_{XRD}	$\overline{XCP}$ to $\overline{RDD}$ Delay	25		70	ns	

8218/19 XSTR TO OUTPUT COMMAND DELAY
ONESHOT DELAY VS. DELAY ADJUST CAPACITANCE AND RESISTANCE



PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

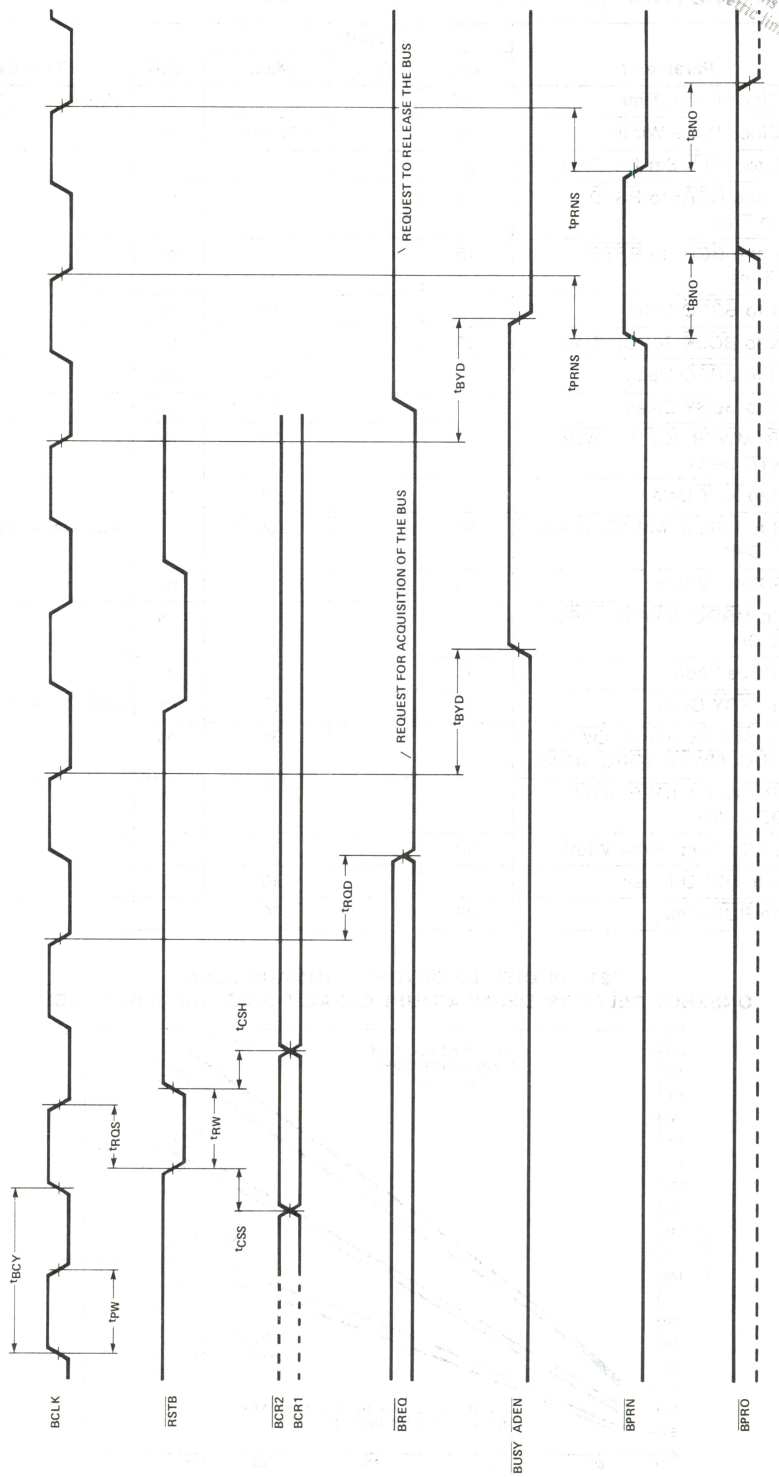


FIGURE 3a. 8218/8219 SYNCHRONOUS BUS TIMING (SYSTEM BUS PREVIOUSLY NOT IN USE).

PRELIMINARY
Notice: This is not a final specification. Some parameter limits are subject to change.

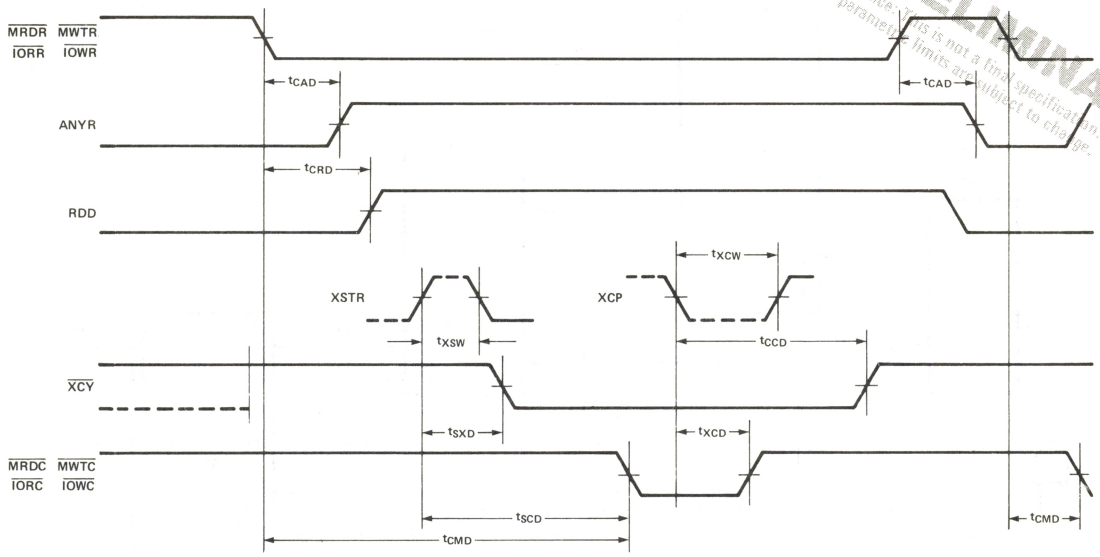


FIGURE 3b. 8218/8219 CONTROL CYCLE (SYSTEM BUS PREVIOUSLY NOT IN USE).

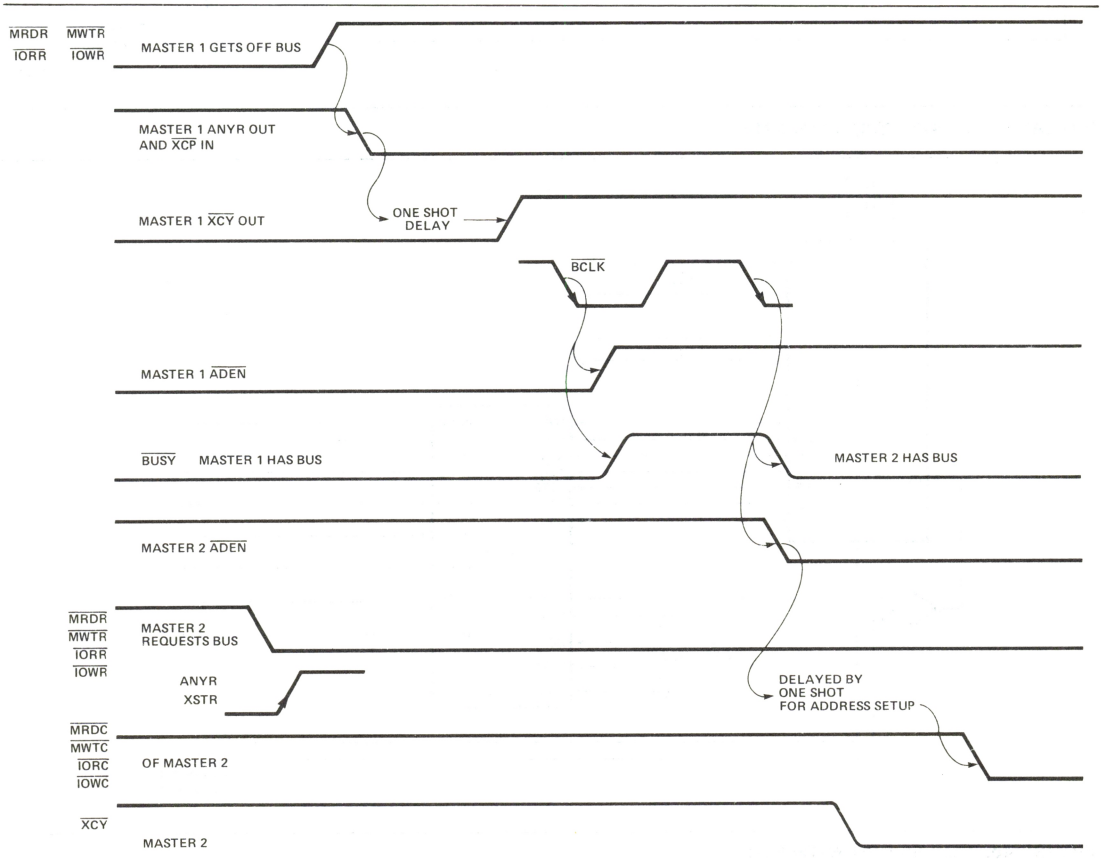


FIGURE 3c. 8218/8219 BUS CONTROL EXCHANGE (MASTER NO. 1 LEAVING BUS AND MASTER NO. 2 GETTING ON BUS).

PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

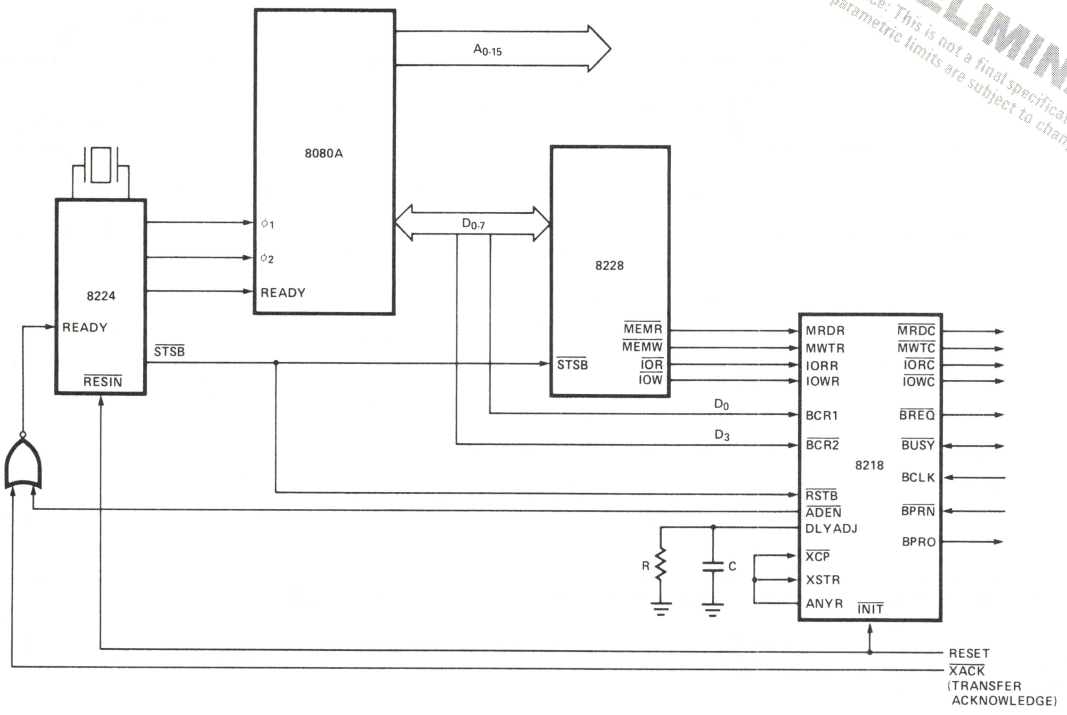


FIGURE 4a. MCS-80 CPU WITH 8218.

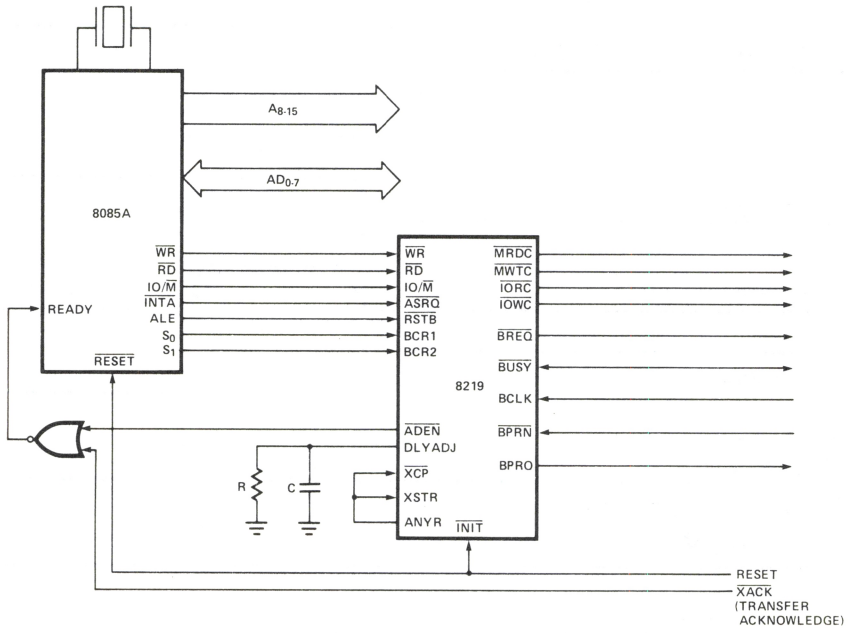


FIGURE 4b. MCS-85 CPU WITH 8219.

PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

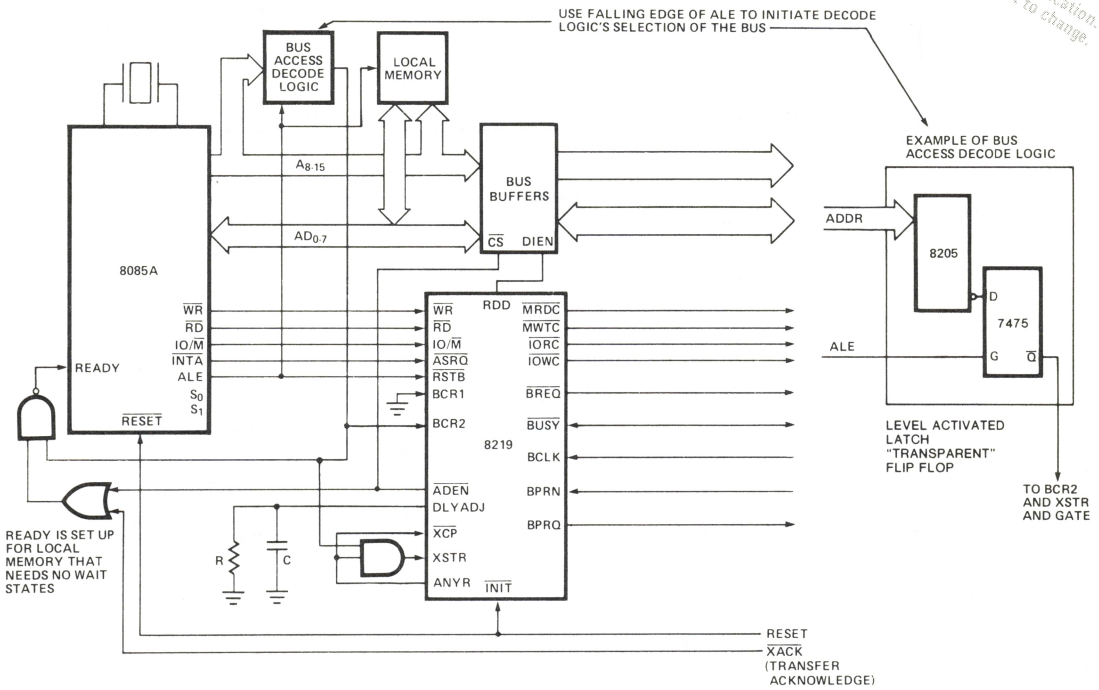


FIGURE 4c. MCS-85 CPU WITH 8219 USING LOCAL MEMORY.

PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

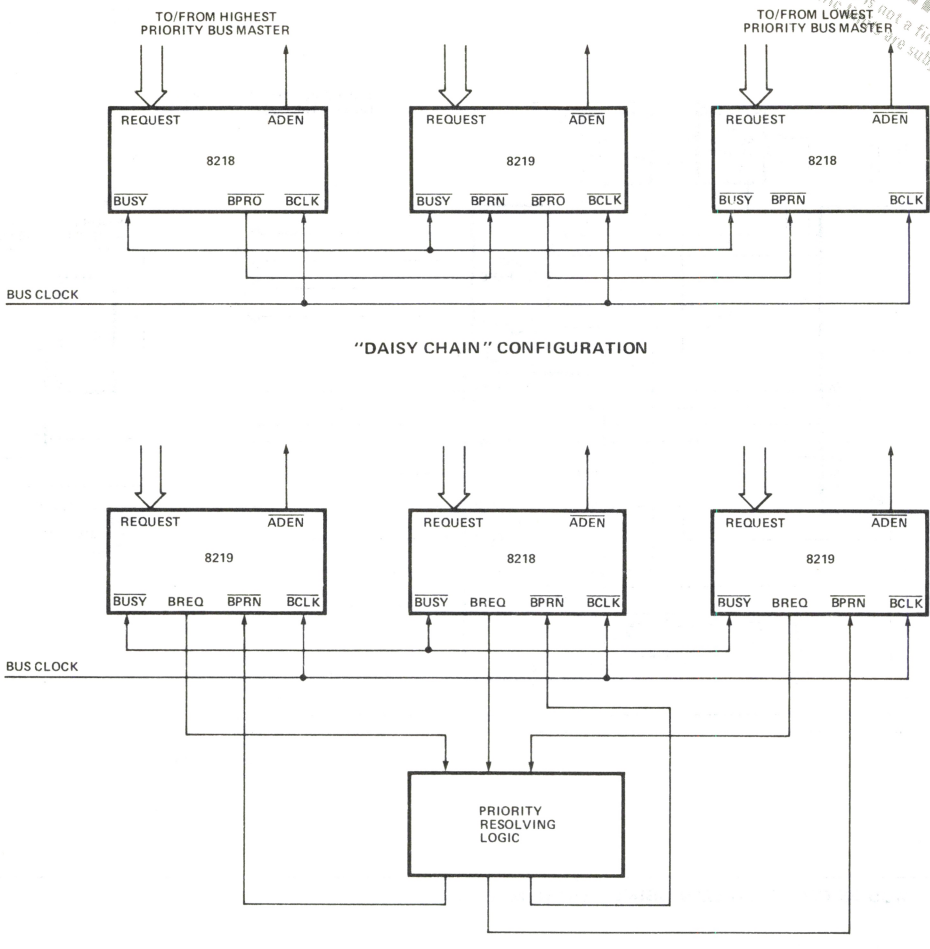


FIGURE 5. TWO METHODS OF CONNECTING MULTIPLE 8218/8219's TO RESOLVE BUS CONTENTION AMONG MULTIPLE MASTERS.

8237/8237-2
HIGH PERFORMANCE PROGRAMMABLE DMA CONTROLLER

- **Enable/Disable Control of Individual DMA Requests**
- **Four Independent DMA Channels**
- **Independent Autoinitialization of all Channels**
- **Memory-to-Memory Transfers**
- **Memory Block Initialization**
- **Address Increment or Decrement**
- **High Performance: Transfers up to 1.6M Bytes/Second with 5 MHz 8237-2**
- **Directly Expandable to any Number of Channels**
- **End of Process Input for Terminating Transfers**
- **Software DMA Requests**
- **Independent Polarity Control for DREQ and DACK Signals**

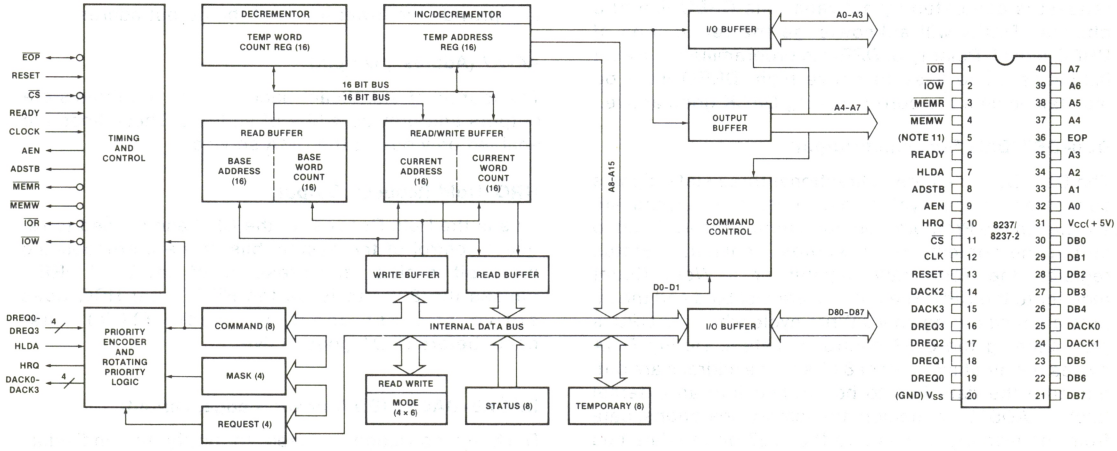
The 8237 Multimode Direct Memory Access (DMA) Controller is a peripheral interface circuit for microprocessor systems. It is designed to improve system performance by allowing external devices to directly transfer information to or from the system memory. Memory-to-memory transfer capability is also provided. The 8237 offers a wide variety of programmable control features to enhance data throughput and system optimization and to allow dynamic reconfiguration under program control.

The 8237 is designed to be used in conjunction with an external 8-bit address register such as the 8282. It contains four independent channels and may be expanded to any number of channels by cascading additional controller chips.

The three basic transfer modes allow programmability of the types of DMA service by the user. Each channel can be individually programmed to Autoinitialize to its original condition following an End of Process (EOP).

Each channel has a full 64K address and word count capability.

The 8237-2 is a 5 MHz selected version of the standard 3 MHz 8237.



BLOCK DIAGRAM

Figure 1. Pin Configuration

PIN DEFINITIONS

V_{CC}: +5 volt supply

V_{SS}: Ground

CLK (Clock, Input)

This input controls the internal operations of the 8237 and its rate of data transfers. The input may be driven at up to 3 MHz for the standard 8237 and up to 5 MHz for the 8237-2.

$\overline{CS}$ (Chip Select, Input)

Chip Select is an active low input used to select the 8237 as an I/O device during the Idle cycle. This allows CPU communication on the data bus.

RESET (Reset, Input)

Reset is an asynchronous active high input which clears the Command, Status, Request and Temporary registers. It also clears the first/last flip/flop and sets the Mask register. Following a Reset the device is in the Idle cycle.

READY (Ready, Input)

Ready is an input used to extend the memory read and write pulses from the 8237 to accommodate slow memories or I/O peripheral devices.

HLDA (Hold Acknowledge, Input)

The active high Hold Acknowledge from the CPU Indicates that control of the system buses have been relinquished.

DREQ0-DREQ3 (DMA Request, Input)

The DMA Request lines are individual asynchronous channel request inputs used by peripheral circuits to obtain DMA service. In Fixed Priority, DREQ0 has the highest priority and DREQ3 has the lowest priority. A request is generated by activating the DREQ line of a channel. DACK will acknowledge the recognition of DREQ signal. Polarity of DREQ is programmable. Reset initializes these lines to active high. DREQ must be maintained until the corresponding DACK goes active.

DB0-DB7 (Data Bus, Input/Output)

The Data Bus lines are bidirectional three-state signals connected to the system data bus. The outputs are enabled in the Program Condition during the I/O Read to output the contents of an Address register, a Status register, the Temporary register or a Word Count register to the CPU. The outputs are disabled and the inputs are read during an I/O Write cycle when the CPU is programming the 8237 control registers. During DMA cycles the most significant 8 bits of the address are output onto the data bus to be strobed into an external latch by ADSTB. In memory-to-memory operations, data from the memory comes into the 8237 on the data bus during the read-from-memory transfer. In the write-to-memory transfer, the data bus outputs place the data into the new memory location.

$\overline{IOR}$ (I/O Read, Input/Output)

I/O Read is a bidirectional active low three-state line. In the Idle cycle, it is an input control signal used by the CPU to read the control registers. In the Active cycle, it is an output control signal used by the 8237 to access data from a peripheral during a DMA Write transfer.

$\overline{IOW}$ (I/O Write, Input/Output)

I/O Write is a bidirectional active low three-state line. In the Idle cycle, it is an input control signal used by the CPU to load information into the 8237. In the Active cycle, it is an output control signal used by the 8237 to load data to the peripheral during a DMA Read transfer.

$\overline{EOP}$ (End of Process, Input/Output)

$\overline{EOP}$ is an active low bidirectional signal. Information concerning the completion of DMA services is available at the bidirectional $\overline{EOP}$ pin. The 8237 allows an external signal to terminate an active DMA service. This is accomplished by pulling the $\overline{EOP}$ input low with an external $\overline{EOP}$ signal. The 8237 also generates a pulse when the terminal count (TC) for any channel is reached. This generates an $\overline{EOP}$ signal which is output through the $\overline{EOP}$ Line. The reception of $\overline{EOP}$, either internal or external, will cause the 8237 to terminate the service, reset the request, and, if Autoinitialize is enabled, to write the base registers to the current registers of that channel. The mask bit and TC bit in the status word will be set for the currently active channel by $\overline{EOP}$ unless the channel is programmed for Autoinitialize. In that case, the mask bit remains clear. During memory-to-memory transfers, $\overline{EOP}$ will be output when the TC for channel 1 occurs. $\overline{EOP}$ should be tied high with a pull-up resistor if it is not used to prevent erroneous end of process inputs.

A0-A3 (Address, Input/Output)

The four least significant address lines are bidirectional three-state signals. In the Idle cycle they are inputs and are used by the 8237 to address the control register to be loaded or read. In the Active cycle they are outputs and provide the lower 4 bits of the output address.

A4-A7 (Address, Output)

The four most significant address lines are three-state outputs and provide 4 bits of address. These lines are enabled only during the DMA service.

HRQ (Hold Request, Output)

This is the Hold Request to the CPU and is used to request control of the system bus. If the corresponding mask bit is clear, the presence of any valid DREQ causes the 8237 to issue the HRQ. After HRQ goes active at least one clock cycle (TCY) must occur before HLDA goes active.

DACK0-DACK3 (DMA Acknowledge, Output)

DMA Acknowledge is used to notify the individual peripherals when one has been granted a DMA cycle. The sense of these lines is programmable. Reset initializes them to active low.

AEN (Address Enable, Output)

This output enables the 8-bit latch containing the upper 8 address bits onto the system address bus. AEN can also be used to disable other system bus drivers during DMA transfers. AEN is active HIGH.

ADSTB (Address Strobe, Output)

The active high Address Strobe is used to strobe the upper address byte into an external latch.

$\overline{\text{MEMR}}$ (Memory Read, Output)

The Memory Read signal is an active low three-state output used to access data from the selected memory location during a DMA Read or a memory-to-memory transfer.

$\overline{\text{MEMW}}$ (Memory Write, Output)

The Memory Write signal is an active low three-state output used to write data to the selected memory location during a DMA Write or a memory-to-memory transfer.

FUNCTIONAL DESCRIPTION

The 8237 block diagram includes the major logic blocks and all of the internal registers. The data interconnection paths are also shown. Not shown are the various control signals between the blocks. The 8237 contains 344 bits of internal memory in the form of registers. Figure 2 lists these registers by name and shows the size of each. A detailed description of the registers and their functions can be found under Register Description.

Name	Size	Number
Base Address Registers	16 bits	4
Base Word Count Registers	16 bits	4
Current Address Registers	16 bits	4
Current Word Count Registers	16 bits	4
Temporary Address Register	16 bits	1
Temporary Word Count Register	16 bits	1
Status Register	8 bits	1
Command Register	8 bits	1
Temporary Register	8 bits	1
Mode Registers	6 bits	4
Mask Register	4 bits	1
Request Register	4 bits	1

Figure 2. 8237 Internal Registers

The 8237 contains three basic blocks of control logic. The Timing Control block generates internal timing and external control signals for the 8237. The Program Command Control block decodes the various commands given to the 8237 by the microprocessor prior to servicing a DMA Request. It also decodes the Mode Control word used to select the type of DMA during the servicing. The Priority Encoder block resolves priority contention between DMA channels requesting service simultaneously.

The Timing Control block derives internal timing from the clock input. In 8237 systems this input will usually be the $\phi 2$ TTL clock from an 8224 or CLK from an 8085A. However, any appropriate system clock will suffice.

DMA OPERATION

The 8237 is designed to operate in two major cycles. These are called Idle and Active cycles. Each device cycle is made up of a number of states. The 8237 can assume seven separate states, each composed of one full clock period. State I (SI) is the inactive state. It is entered when the 8237 has no valid DMA requests pending. While in SI, the DMA controller is inactive but may be in the Program Condition, being programmed by the processor. State O (SO) is the first state of a DMA service. The 8237 has requested a hold but the processor has not yet returned an acknowledge. An acknowledge from the CPU will signal that transfers may begin. S1, S2, S3 and S4 are the working states of the DMA service. If more time is needed to complete a transfer than is available with normal timing, wait states (SW) can be inserted between S2 or S3 and S4 by the use of the Ready line on the 8237.

Memory-to-memory transfers require a read-from and a write-to-memory to complete each transfer. The states, which resemble the normal working states, use two digit numbers for identification. Eight states are required for a single transfer. The first four states (S11, S12, S13, S14) are used for the read-from-memory half and the last four states (S21, S22, S23, S24) for the write-to-memory half of the transfer.

IDLE CYCLE

When no channel is requesting service, the 8237 will enter the Idle cycle and perform "SI" states. In this cycle the 8237 will sample the DREQ lines every clock cycle to determine if any channel is requesting a DMA service. The device will also sample $\overline{\text{CS}}$, looking for an attempt by the microprocessor to write or read the internal registers of the 8237. When $\overline{\text{CS}}$ is low and HRQ is low, the 8237 enters the Program Condition. The CPU can now establish, change or inspect the internal definition of the part by reading from or writing to the internal registers. Address lines A0–A3 are inputs to the device and select which registers will be read or written. The $\overline{\text{IOR}}$ and $\overline{\text{IOW}}$ lines are used to select and time reads or writes. Due to the number and size of the internal registers, an internal flip-flop is used to generate an additional bit of address. This bit is used to determine the upper or lower byte of the 16-bit Address and Word Count registers. The flip-flop is reset by Master Clear or Reset. A separate software command can also reset this flip-flop.

Special software commands can be executed by the 8237 in the Program Condition. These commands are decoded as sets of addresses with the $\overline{\text{CS}}$ and $\overline{\text{IOW}}$. The commands do not make use of the data bus. Instructions include Clear First/Last Flip-flop and Master Clear.

ACTIVE CYCLE

When the 8237 is in the Idle cycle and a channel requests a DMA service, the device will output an HRQ to the microprocessor and enter the Active cycle. It is in this cycle that the DMA service will take place, in one of four modes:

Single Transfer Mode — In Single Transfer mode the device is programmed to make one transfer only. The

word count will be decremented and the address decremented or incremented following each transfer. When the word count goes to zero, a Terminal Count (TC) will cause an Autoinitialize if the channel has been programmed to do so.

DREQ must be held active until DACK becomes active in order to be recognized. If DREQ is held active throughout the single transfer, HRQ will go inactive and release the bus to the system. It will again go active and, upon receipt of a new HLDA, another single transfer will be performed. In 8080A/8085A systems this will ensure one full machine cycle execution between DMA transfers. Details of timing between the 8237 and other bus control protocols will depend upon the characteristics of the microprocessor involved.

Block Transfer Mode — In Block Transfer mode the device is activated by DREQ to continue making transfers during the service until a TC, caused by word count going to zero, or an external End of Process ($\overline{EOP}$) is encountered. DREQ need only be held active until DACK becomes active. Again, an Autoinitialization will occur at the end of the service if the channel has been programmed for it.

Demand Transfer Mode — In Demand Transfer mode the device is programmed to continue making transfers until a TC or external $\overline{EOP}$ is encountered or until DREQ goes inactive. Thus transfers may continue until the I/O device has exhausted its data capacity. After the I/O device has had a chance to catch up, the DMA service is re-established by means of a DREQ. During the time between services when the microprocessor is allowed to operate, the intermediate values of address and word count are stored in the 8237 Current Address and Current Word Count registers. Only an $\overline{EOP}$ can cause an Autoinitialize at the end of the service. $\overline{EOP}$ is generated either by TC or by an external signal.

Cascade Mode — This mode is used to cascade more than one 8237 together for simple system expansion. The HRQ and HLDA signals from the additional 8237 are connected to the DREQ and DACK signals of a channel of the initial 8237. This allows the DMA requests of the additional device to propagate through the priority network circuitry of the preceding device. The priority chain is preserved and the new device must wait for its turn to acknowledge requests. Since the cascade channel in the initial device is used only for prioritizing the additional device, it does not output any address or control signals of its own. These would conflict with the outputs of the active channel in the added device. The 8237 will respond to DREQ and DACK but all other outputs except HRQ will be disabled.

Figure 3 shows two additional devices cascaded into an initial device using two of the previous channels. This forms a two level DMA system. More 8237s could be added at the second level by using the remaining channels of the first level. Additional devices can also be added by cascading into the channels of the second level devices, forming a third level.

TRANSFER TYPES

Each of the three active transfer modes can perform three different types of transfers. These are Read, Write and Verify. Write transfers move data from an I/O device to the memory by activating $\overline{MEMW}$ and $\overline{IOR}$. Read transfers move data from memory to an I/O device by activating MEMR and $\overline{IOW}$. Verify transfers are pseudo transfers. The 8237 operates as in Read or Write transfers generating addresses, and responding to EOP, etc. However, the memory and I/O control lines all remain inactive.

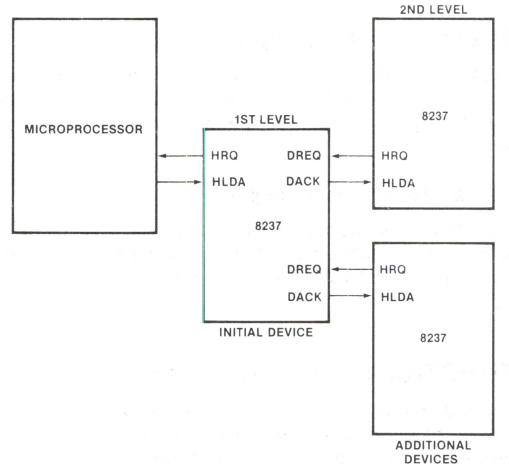


Figure 3. Cascaded 8237s

Memory-to-Memory — To perform block moves of data from one memroy address space to another with a minimum of program effort and time, the 8237 includes a memory-to-memory transfer feature. Programming a bit in the Command register selects channels 0 and 1 to operate as memory-to-memory transfer channels. The transfer is initiated by setting the software DREQ for channel 0. The 8237 requests a DMA service in the normal manner. After HLDA is true, the device, using eight-state transfers in Block Transfer mode, reads data from the memory. The channel 0 Current Address register is the source for the address used and is decremented or incremented in the normal manner. The data byte read from the memory is stored in the 8237 internal Temporary register. Channel 1 then writes the data from the Temporary register to memory using the address in its Current Address register and incrementing or decrementing it in the normal manner. The channel 1 Current Word Count is decremented. When the word count of channel 1 goes to zero, a TC is generated causing an $\overline{EOP}$ output, terminating the service.

Channel 0 may be programmed to retain the same address for all transfers. This allows a single word to be written to a block of memory.

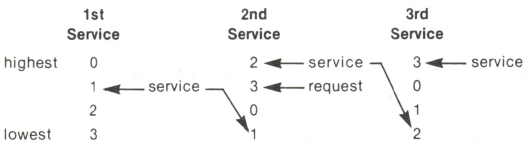
The 8237 will respond to external $\overline{EOP}$ signals during memory-to-memory transfers. Data comparators in block search schemes may use this input to terminate the service when a match is found. The timing of memory-to-memory transfers is found in Diagram 4. Memory-to-memory operations can be detected as an active AEN with no DACK outputs.

Autoinitialize — By programming a bit in the Mode register, a channel may be set up as an Autoinitialize

channel. During Autoinitialize initialization, the original values of the Current Address and Current Word Count registers are automatically restored from the Base Address and Base Word Count registers of that channel following $\overline{EOP}$. The base registers are loaded simultaneously with the current registers by the microprocessor and remain unchanged throughout the DMA service. The mask bit is not set when the channel is in Autoinitialize. Following Autoinitialize the channel is ready to perform another service without CPU intervention.

Priority — The 8237 has two types of priority encoding available as software selectable options. The first is Fixed Priority which fixes the channels in priority order based upon the descending value of their number. The channel with the lowest priority is 3 followed by 2, 1 and the highest priority channel, 0. After the recognition of any one channel for service, the other channels are prevented from interferring with that service until it is completed.

The second scheme is Rotating Priority. The last channel to get service becomes the lowest priority channel with the others rotating accordingly.



With Rotating Priority in a single chip DMA system, any device requesting service is guaranteed to be recognized after no more than three higher priority services have occurred. This prevents any one channel from monopolizing the system.

Compressed Timing — In order to achieve even greater throughput where system characteristics permit, the 8237 can compress the transfer time to two clock cycles. From Timing Diagram 3 it can be seen that state S3 is used to extend the access time of the read pulse. By removing state S3, the read pulse width is made equal to the write pulse width and a transfer consists only of state S2 to change the address and state S4 to perform the read/write. S1 states will still occur when A8-A15 need updating (see Address Generation). Timing for compressed transfers is found in Diagram 6.

Address Generation — In order to reduce pin count, the 8237 multiplexes the eight higher order address bits on the data lines. State S1 is used to output the higher order address bits to an external latch from which they may be placed on the address bus. The falling edge of Address Strobe (ADSTB) is used to load these bits from the data lines to the latch. Address Enable (AEN) is used to enable the bits onto the address bus through a three-state enable. The lower order address bits are output by the 8237 directly. Lines A0-A7 should be connected to the address bus. Timing Diagram 3 shows the time relationships between CLK, AEN, ADSTB, DB0-DB7 and A0-A7.

During Block and Demand Transfer mode services, which include multiple transfers, the addresses generated will be sequential. For many transfers the data held in the external address latch will remain the same. This data need only change when a carry or borrow from A7 to A8 takes place in the normal sequence of addresses. To save time and speed transfers, the 8237 executes S1 states only when updating of A8-A15 in the latch is necessary. This means for long services, S1 states may occur only once every 256 transfers, a savings of 255 clock cycles for each 256 transfers.

REGISTER DESCRIPTION

Current Address Register — Each channel has a 16-bit Current Address register. This register holds the value of the address used during DMA transfers. The address is automatically incremented or decremented after each transfer and the intermediate values of the address are stored in the Current Address register during the transfer. This register is written or read by the microprocessor in successive 8-bit bytes. It may also be reinitialized by an Autoinitialize back to its original value. Autoinitialize takes place only after an $\overline{EOP}$.

Current Word Register — Each channel has a 16-bit Current Word Count register. This register holds the number of transfers to be performed. The word count is decremented after each transfer. The intermediate value of the word count is stored in the register during the transfer. When the value in the register goes to zero, a TC will be generated. This register is loaded or read in successive 8-bit bytes by the microprocessor in the Program Condition. Following the end of a DMA service it may also be reinitialized by an Autoinitialization back to its original value. Autoinitialize can occur only when an $\overline{EOP}$ occurs.

Base Address and Base Word Count Registers — Each channel has a pair of Base Address and Base Word Count registers. These 16-bit registers store the original value of their associated current registers. During Autoinitialize these values are used to restore the current registers to their original values. The base registers are written simultaneously with their corresponding current register in 8-bit bytes in the Program Condition by the microprocessor. These registers cannot be read by the microprocessor.

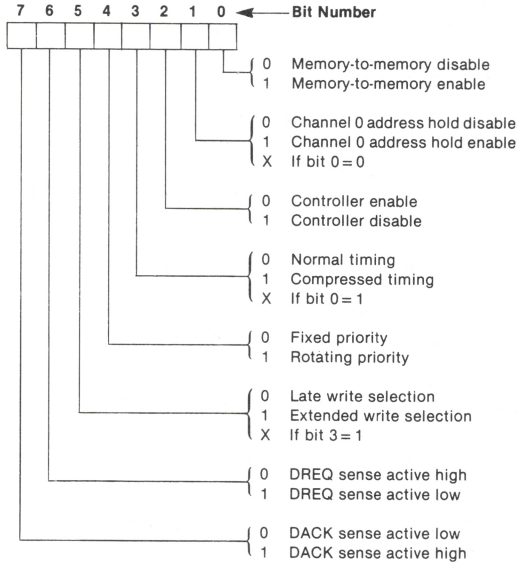
Command Register — This 8-bit register controls the operation of the 8237. It is programmed by the microprocessor in the Program Condition and is cleared by Reset. The following table lists the function of the command bits. See Figure 6 for address coding.

Mode Register — Each channel has a 6-bit Mode register associated with it. When the register is being written to by the microprocessor in the Program Condition, bits 0 and 1 determine which channel Mode register is to be written.

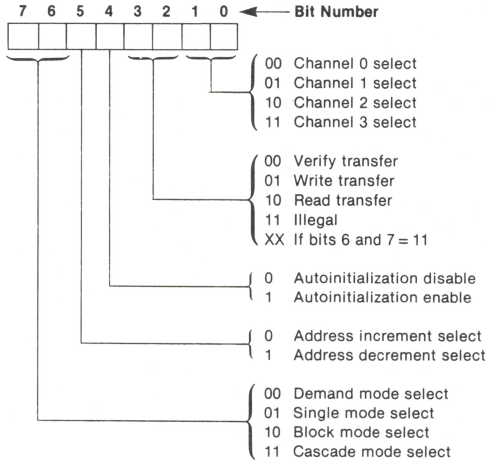
Request Register — The 8237 can respond to requests for DMA service which are initiated by software as well as by a DREQ. Each channel has a request bit associated with it in the 4-bit Request register. These are non-

maskable and subject to prioritization by the Priority Encoder network. Each register bit is set or reset separately under software control or is cleared upon generation of a TC or external $\overline{EOP}$. The entire register is cleared by a Reset. To set or reset a bit, the software loads the proper form of the data word. See Figure 4 for address coding.

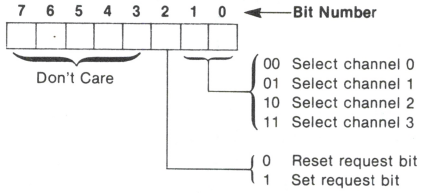
Command Register



Mode Register

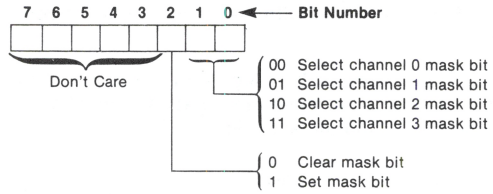


Request Register

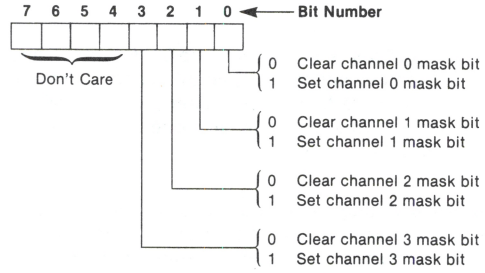


Software requests will be serviced only if the channel is in Block mode. When initiating a memory-to-memory transfer, the software request for channel 0 should be set.

Mask Register — Each channel has associated with it a mask bit which can be set to disable the incoming DREQ. Each mask bit is set when its associated channel produces an $\overline{EOP}$ if the channel is not programmed for Autoinitialize. Each bit of the 4-bit Mask register may also be set or cleared separately under software control. The entire register is also set by a Reset. This disables all DMA requests until a clear Mask register instruction allows them to occur. The instruction to separately set or clear the mask bits is similar in form to that used with the Request register. See Figure 4 for instruction addressing.



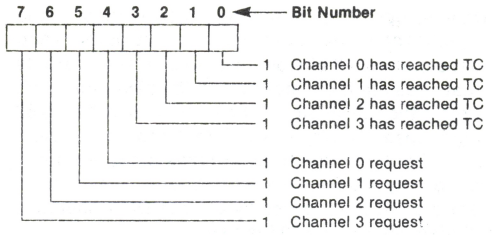
All four bits of the Mask register may also be written with a single command.



Register	Operation	Signals						
		$\overline{CS}$	$\overline{IOR}$	$\overline{IOW}$	A3	A2	A1	A0
Command	Write	0	1	0	1	0	0	0
Mode	Write	0	1	0	1	0	1	1
Request	Write	0	1	0	1	0	0	1
Mask	Set/Reset	0	1	0	1	0	1	0
Mask	Write	0	1	0	1	1	1	1
Temporary	Read	0	0	1	1	1	0	1
Status	Read	0	0	1	1	0	0	0

Figure 4. Definition of Register Codes

Status Register — The Status register is available to be read out of the 8237 by the microprocessor. It contains information about the status of the devices at this point. This information includes which channels have reached a terminal count and which channels have pending DMA requests. Bits 0-3 are set every time a TC is reached by that channel or an external $\overline{EOP}$ is applied. These bits are cleared upon Reset and on each Status Read. Bits 4-7 are set whenever their corresponding channel is requesting service.



Temporary Register — The Temporary register is used to hold data during memory-to-memory transfers. Following the completion of the transfers, the last word moved can be read by the microprocessor in the Program Condition. The Temporary register always contains the last byte transferred in the previous memory-to-memory operation, unless cleared by a Reset.

Software Commands — These are additional special software commands which can be executed in the Program Condition. They do not depend on any specific bit pattern on the data bus. The two software commands are:

Clear First/Last Flip-Flop: This command is executed prior to writing or reading new address or word count information to the 8237. This initializes the flip-flop to a known state so that subsequent accesses to register contents by the microprocessor will address upper and lower bytes in the correct sequence.

Master Clear: This software instruction has the same effect as the hardware Reset. The Command, Status, Request, Temporary, and Internal First/Last Flip-Flop registers are cleared and the Mask register is set. The 8237 will enter the Idle cycle.

Figure 5 lists the address codes for the software commands:

Signals						Operation
A3	A2	A1	A0	$\overline{IOR}$	$\overline{IOW}$	
1	0	0	0	0	1	Read Status Register
1	0	0	0	1	0	Write Command Register
1	0	0	1	0	1	Illegal
1	0	0	1	1	0	Write Request Register
1	0	1	0	0	1	Illegal
1	0	1	0	1	0	Write Single Mask Register Bit
1	0	1	1	0	1	Illegal
1	0	1	1	1	0	Write Mode Register
1	1	0	0	0	1	Illegal
1	1	0	0	1	0	Clear Byte Pointer Flip/Flop
1	1	0	1	0	1	Read Temporary Register
1	1	0	1	1	0	Master Clear
1	1	1	0	0	1	Illegal
1	1	1	0	1	0	Illegal
1	1	1	1	0	1	Illegal
1	1	1	1	1	0	Write All Mask Register Bits

Figure 5. Software Command Codes

Channel	Register	Operation	Signals							Internal Flip-Flop	Data Bus DB0–DB7
			$\overline{CS}$	$\overline{IOR}$	$\overline{IOW}$	A3	A2	A1	A0		
0	Base and Current Address	Write	0	1	0	0	0	0	0	0	A0–A7
			0	1	0	0	0	0	0	1	A8–A15
	Current Address	Read	0	0	1	0	0	0	0	0	A0–A7
			0	0	1	0	0	0	0	1	A8–A15
	Base and Current Word Count	Write	0	1	0	0	0	0	1	0	W0–W7
			0	1	0	0	0	0	1	1	W8–W15
	Current Word Count	Read	0	0	1	0	0	0	1	0	W)0–W7
			0	0	1	0	0	0	1	1	W8–W15
1	Base and Current Address	Write	0	1	0	0	0	1	0	0	A0–A7
			0	1	0	0	0	1	0	1	A8–A15
	Current Address	Read	0	0	1	0	0	1	0	0	A0–A7
			0	0	1	0	0	1	0	1	A8–A15
	Base and Current Word Count	Write	0	1	0	0	0	1	1	0	W0–W7
			0	1	0	0	0	1	1	1	W8–W15
	Current Word Count	Read	0	0	1	0	0	1	1	0	W)0–W7
			0	0	1	0	0	1	1	1	W8–W15
2	Base and Current Address	Write	0	1	0	0	1	0	0	0	A0–A7
			0	1	0	0	1	0	0	1	A8–A15
	Current Address	Read	0	0	1	0	1	0	0	0	A0–A7
			0	0	1	0	1	0	0	1	A8–A15
	Base and Current Word Count	Write	0	1	0	0	1	0	1	0	W0–W7
			0	1	0	0	1	0	1	1	W8–W15
	Current Word Count	Read	0	0	1	0	1	0	1	0	W)0–W7
			0	0	1	0	1	0	1	1	W8–W15
3	Base and Current Address	Write	0	1	0	0	1	1	0	0	A0–A7
			0	1	0	0	1	1	0	1	A8–A15
	Current Address	Read	0	0	1	0	1	1	0	0	A0–A7
			0	0	1	0	1	1	0	1	A8–A15
	Base and Current Word Count	Write	0	1	0	0	1	1	1	0	W0–W7
			0	1	0	0	1	1	1	1	W8–W15
	Current Word Count	Read	0	0	1	0	1	1	1	0	W)0–W7
			0	0	1	0	1	1	1	1	W8–W15

Figure 6. Word Count and Address Register Command Codes

APPLICATION INFORMATION

Figure 7 shows a convenient method for configuring a DMA system with the 8237 controller and an 8080A/8085A microprocessor system. The multimode DMA controller issues a HRQ to the processor whenever there is at least one valid DMA request from a peripheral device. When the processor replies with a HLDA signal, the 8237 takes control of the address bus, the data bus and the control bus. The address for the first transfer operation comes out in two bytes — the least significant 8 bits on the eight address outputs and the most significant 8 bits on the data bus. The contents of the data bus are then latched into the 8282 8-bit latch to complete the full 16 bits of the address bus. The 8282 is a high speed, 8-bit, three-state latch in a 20-pin package. After the initial transfer takes place, the latch is updated only after a carry or borrow is generated in the least significant address byte. Four DMA channels are provided when one 8237 is used.

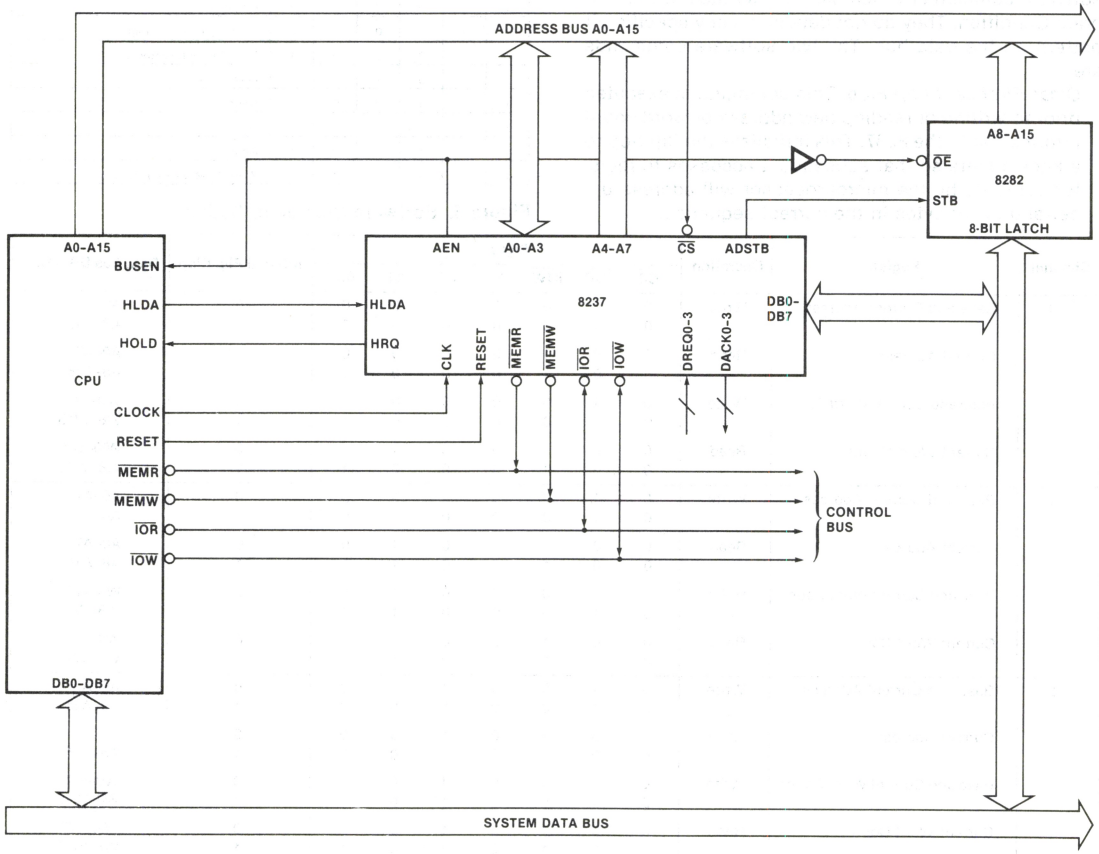


Figure 7. 8237 System Interface

ABSOLUTE MAXIMUM RATINGS*

Ambient Temperature under Bias ..... 0°C to 70°C
Storage Temperature ..... −65°C to +150°C
Voltage on any Pin with
Respect to Ground ..... −0.5 to 7V
Power Dissipation ..... 1.5 Watt

*COMMENT: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

D.C. CHARACTERISTICS

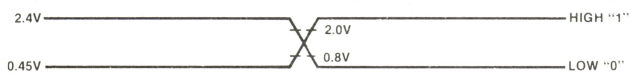
$T_A = 0°C$ to $70°C$, $V_{CC} = 5.0V \pm 5\%$, $GND = 0V$

Symbol	Parameter	Min.	Typ.(1)	Max.	Unit	Test Conditions
V_{OH}	Output HIGH Voltage	2.4			V	$I_{OH} = -200\ \mu A$
		3.3			V	$I_{OH} = -100\ \mu A$ (HRQ Only)
V_{OL}	Output LOW Voltage			0.4	V	$I_{OL} = 3.2$ mA
V_{IH}	Input HIGH Voltage	2.0		$V_{CC} + 0.5$	V	
V_{IL}	Input LOW Voltage	−0.5		0.8	V	
I_{LI}	Input Load Current			± 10	μA	$V_{SS} \leq V_I \leq V_{CC}$
I_{LO}	Output Leakage Current			± 10	μA	$V_{CC} \leq V_O \leq V_{SS} + 0.40$
I_{CC}	V_{CC} Supply Current		65	130	mA	$T_A = +25°C$
			75	150	mA	$T_A = 0°C$
C_O	Output Capacitance		4	8	pF	fc = 1.0 MHz, Inputs = 0V
C_I	Input Capacitance		8	15	pF	
C_{IO}	I/O Capacitance		10	18	pF	

Notes:

1. Typical values are for $T_A = 25°C$, nominal supply voltage and nominal processing parameters.
2. Input timing parameters assume transition times of 20 ns or less. Waveform measurement points for both input and output signals are 2.0V for HIGH and 0.8V for LOW, unless otherwise noted.
3. Output loading is 1 TTL gate plus 50 pF capacitance, unless otherwise noted.
4. The net $\overline{IOW}$ or $\overline{MEMW}$ Pulse width for normal write will be TCY−100 ns and for extended write will be 2TCY−100 ns. The net $\overline{IOR}$ or $\overline{MEMR}$ pulse width for normal read will be 2TCY−50 ns and for compressed read will be TCY−50 ns.
5. TDQ is specified for two different output HIGH levels. TDQ1 is measured at 2.0V. TDQ2 is measured at 3.3V. The value for TDQ2 assumes an external 3.3 kΩ pull-up resistor connected from HRQ to V_{CC}.
6. DREQ should be held active until DACK is returned.
7. DREQ and DACK signals may be active high or active low. Timing diagrams assume the active high mode.
8. Output loading on the data bus is 1 TTL gate plus 100 pF capacitance.
9. Successive read and/or write operations by the external processor to program or examine the controller must be timed to allow at least 600 ns for the 8237 and at least 400 ns for the 8237-2 as recovery time between active read or write pulses.
10. Parameters are listed in alphabetical order.
11. Pin 5 is an input that should always be at a logic high level. An internal pull-up resistor will establish a logic high when the pin is left floating. Alternatively, pin 5 may be tied to V_{CC}.

A.C. TEST WAVEFORM



A.C. CHARACTERISTICS: DMA (MASTER) MODE

$T_A = 0°C$ to $70°C$, $V_{CC} = 5.0V \pm 5\%$, $GND = 0V$

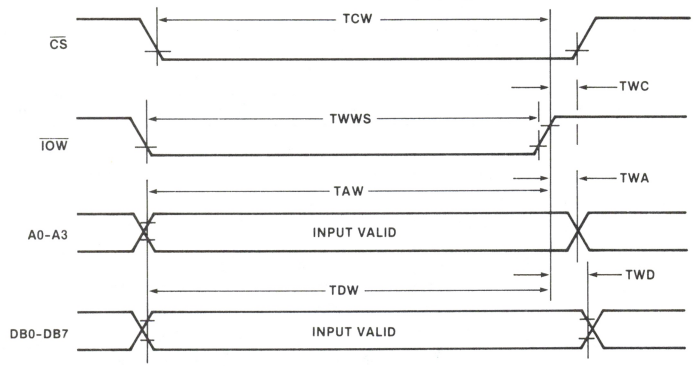
Symbol	Parameter	8237		8237-2		Unit
		Min.	Max.	Min.	Max.	
TAEL	AEN HIGH from CLK LOW (S1) Delay Time		300		200	ns
TAET	AEN LOW from CLK HIGH (S1) Delay Time		200		130	ns
TAFAB	ADR Active to Float Delay from CLK HIGH		150		90	ns
TAFC	$\overline{READ}$ or $\overline{WRITE}$ Float from CLK HIGH		150		120	ns
TAFDB	DB Active to Float Delay from CLK HIGH		250		170	ns
TAHR	ADR from $\overline{READ}$ HIGH Hold Time	TCY-100		TCY-100		ns
TAHS	DB from ADSTB LOW Hold Time	50		30		ns
TAHW	ADR from $\overline{WRITE}$ HIGH Hold Time	TCY-50		TCY-50		ns
TAK	DACK Valid from CLK LOW Delay Time		250		170	ns
	$\overline{EOP}$ HIGH from CLK HIGH Delay Time		250		170	ns
	$\overline{EOP}$ LOW to CLK HIGH Delay Time		250		100	ns
TASM	ADR Stable from CLK HIGH		250		170	ns
TASS	DB to ADSTB LOW Setup Time	100		100		ns
TCH	Clock High Time (Transitions $\leqslant$10 ns)	120		70		ns
TCL	Clock LOW Time (Transitions $\leqslant$10 ns)	150		50		ns
TCY	CLK Cycle Time	320		200		ns
TDCL	CLK HIGH to $\overline{READ}$ or $\overline{WRITE}$ LOW Delay (Note 4)		270		190	ns
TDCTR	$\overline{READ}$ HIGH from CLK HIGH (S4) Delay Time (Note 4)		270		190	ns
TDCTW	$\overline{WRITE}$ HIGH from CLK HIGH (S4) Delay Time (Note 4)		200		130	ns
TDQ1	HRQ Valid from CLK HIGH Delay Time (Note 5)		160		120	ns
TDQ2			250		120	ns
TEPS	$\overline{EOP}$ LOW from CLK LOW Setup Time	60		40		ns
TEPW	$\overline{EOP}$ Pulse Width	300		220		ns
TFAAB	ADR Float to Active Delay from CLK HIGH		250		170	ns
TFAC	$\overline{READ}$ or $\overline{WRITE}$ Active from CLK HIGH		200		150	ns
TFADB	DB Float to Active Delay from CLK HIGH		300		200	ns
THS	HCDA Valid to CLK HIGH Setup Time	100		75		ns
TIDH	Input Data from $\overline{MEMR}$ HIGH Hold Time	0		0		ns
TIDS	Input Data to $\overline{MEMR}$ HIGH Setup Time	250		170		ns
TODH	Output Data from $\overline{MEMW}$ HIGH Hold Time	20		10		ns
TODV	Output Data Valid to $\overline{MEMW}$ HIGH	200		130		ns
TQS	DREQ to CLK LOW (SI, S4) Setup Time	0		0		ns
TRH	CLK to READY LOW Hold Time	20		20		ns
TRS	READY to CLK LOW Setup Time	100		75		ns
TSTL	ADSTB HIGH from CLK HIGH Delay Time		200		130	ns
TSTT	ADSTB LOW from CLK HIGH Delay Time		140		90	ns

A.C. CHARACTERISTICS: PERIPHERAL (SLAVE) MODE

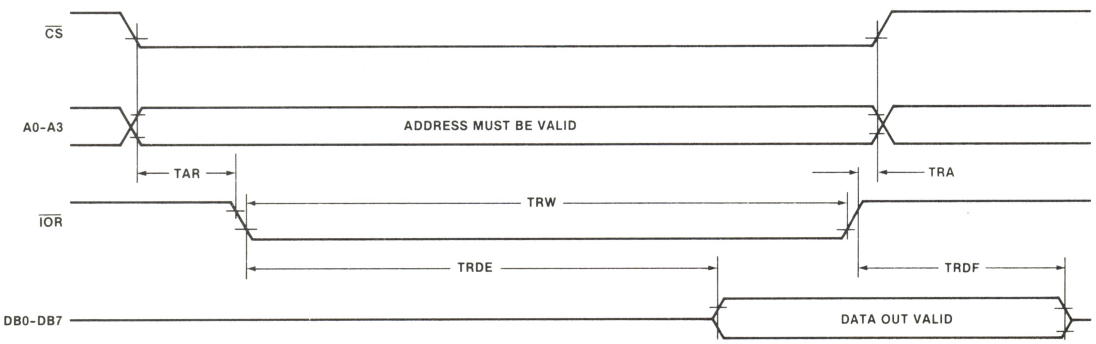
$T_A = 0°C$ to $70°C$, $V_{CC} = 5.0V \pm 5\%$, $GND = 0V$

Symbol	Parameter	8237		8237-2		Unit
		Min.	Max.	Min.	Max.	
TAR	ADR Valid or $\overline{CS}$ LOW to $\overline{READ}$ LOW	50		50		ns
TAW	ADR Valid to $\overline{WRITE}$ HIGH Setup Time	200		160		ns
TCW	CS LOW to $\overline{WRITE}$ HIGH Setup Time	200		160		ns
TDW	Data Valid to $\overline{WRITE}$ HIGH Setup Time	200		160		ns
TRA	ADR or CS Hold from $\overline{READ}$ HIGH	0		0		ns
TRDE	Data Access from $\overline{READ}$ LOW (Note 8)		200		140	ns
TRDF	DB Float Delay from $\overline{READ}$ HIGH	20	100	0	70	ns
TRSTD	Power Supply HIGH to RESET LOW Setup Time	500		500		μs
TRSTS	RESET to First $\overline{IOWR}$	2TCY		2TCY		ns
TRSTW	RESET Pulse Width	300		300		ns
TRW	$\overline{READ}$ Width	300		200		ns
TWA	ADR from $\overline{WRITE}$ HIGH Hold Time	20		0		ns
TWC	$\overline{CS}$ HIGH from $\overline{WRITE}$ HIGH Hold Time	20		0		ns
TWD	Data from $\overline{WRITE}$ HIGH Hold Time	30		10		ns
TWWS	Write Width	200		160		ns

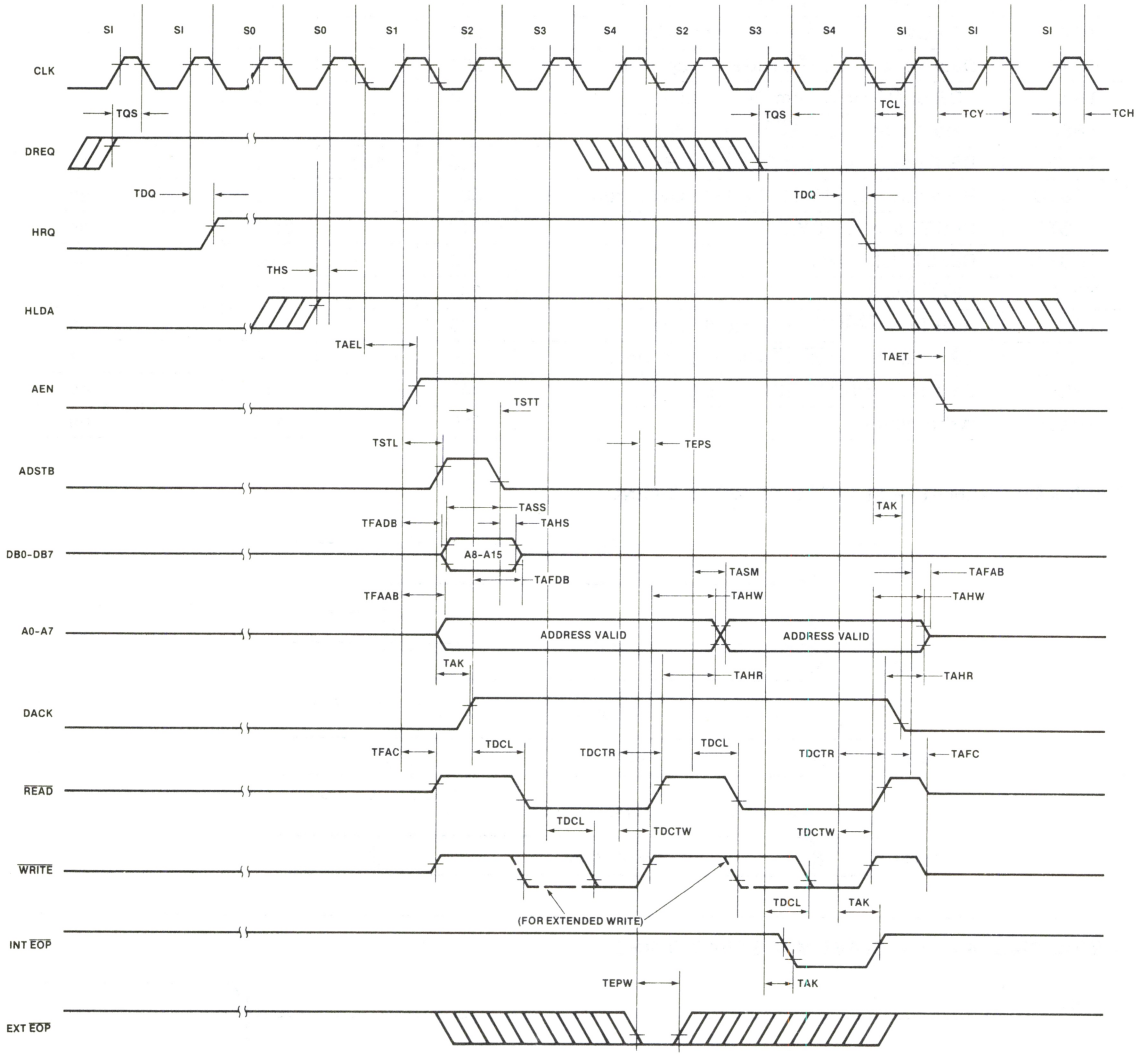
TIMING DIAGRAM #1 — SLAVE MODE WRITE TIMING



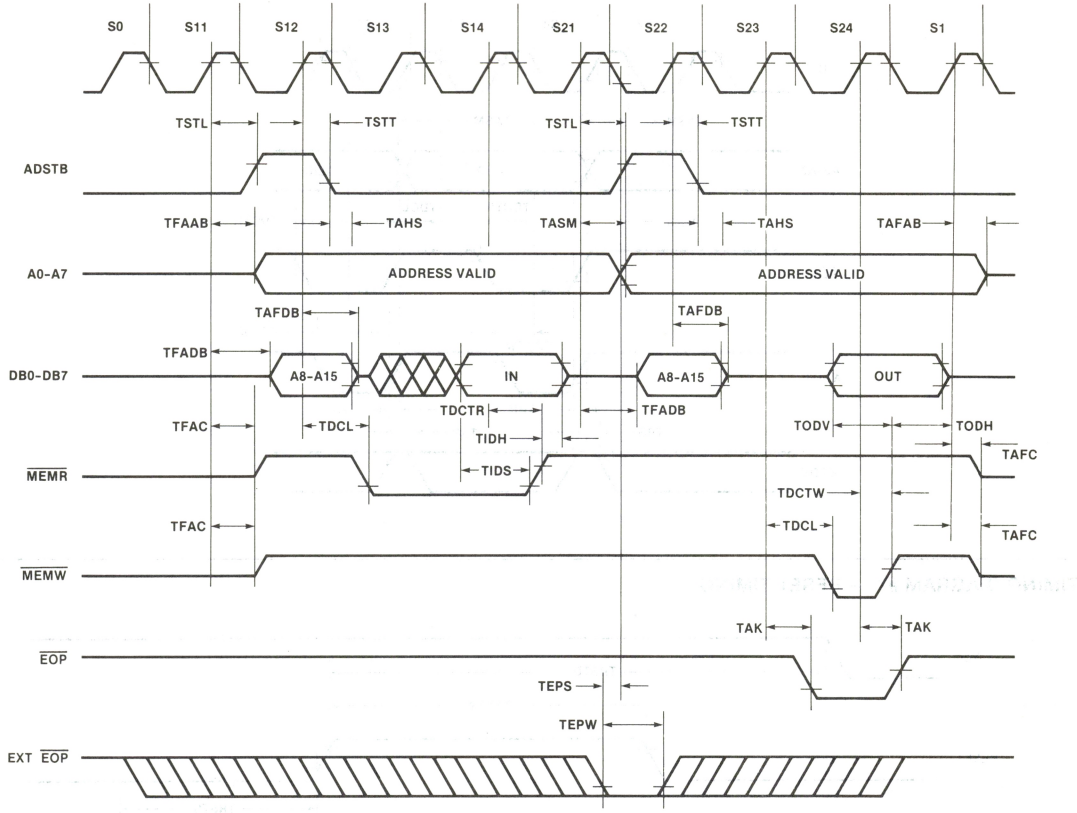
TIMING DIAGRAM #2 — SLAVE MODE READ TIMING



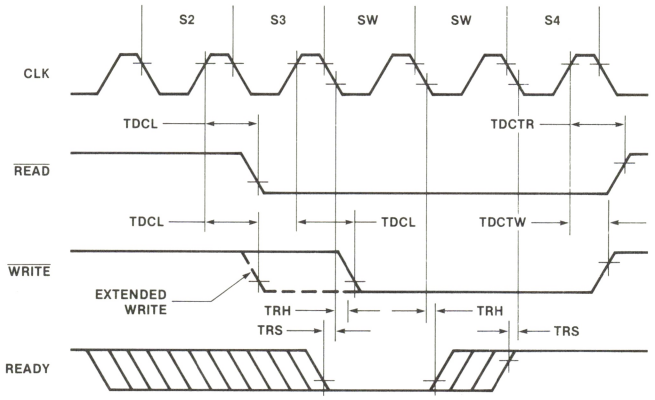
TIMING DIAGRAM #3 — DMA TRANSFER TIMING



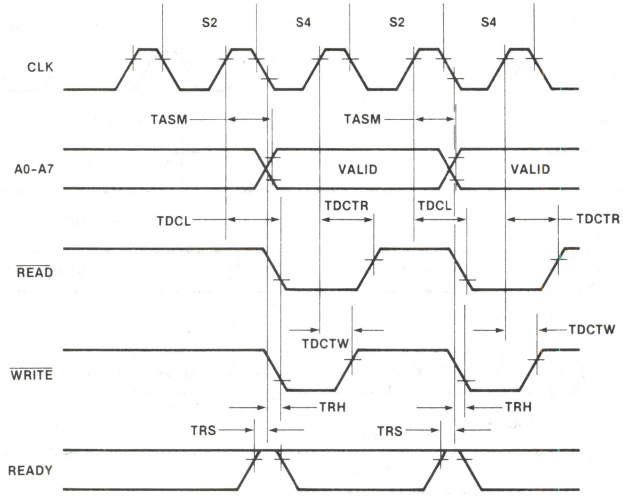
TIMING DIAGRAM #4 — MEMORY TO MEMORY TRANSFER TIMING



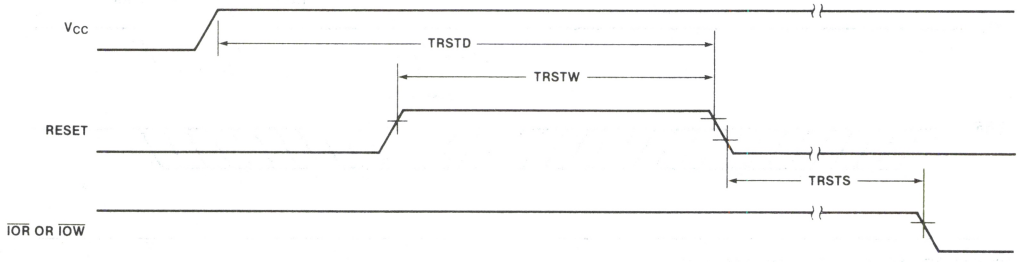
TIMING DIAGRAM #5 — READY TIMING



TIMING DIAGRAM #6 — COMPRESSED TRANSFER TIMING



TIMING DIAGRAM #7 — RESET TIMING

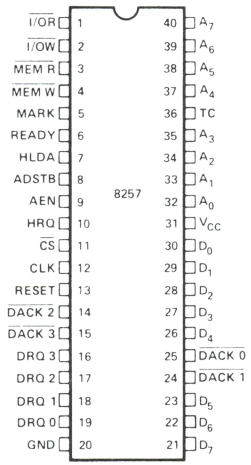


8257/8257-5
PROGRAMMABLE DMA CONTROLLER

- MCS-85™ Compatible 8257-5
- 4-Channel DMA Controller
- Priority DMA Request Logic
- Channel Inhibit Logic
- Terminal Count and Modulo 128 Outputs
- Single TTL Clock
- Single +5V Supply
- Auto Load Mode

The Intel® 8257 is a 4-channel direct memory access (DMA) controller. It is specifically designed to simplify the transfer of data at high speeds for the Intel® microcomputer systems. Its primary function is to generate, upon a peripheral request, a sequential memory address which will allow the peripheral to read or write data directly to or from memory. Acquisition of the system bus in accomplished via the CPU's hold function. The 8257 has priority logic that resolves the peripherals requests and issues a composite hold request to the CPU. It maintains the DMA cycle count for each channel and outputs a control signal to notify the peripheral that the programmed number of DMA cycles is complete. Other output control signals simplify sectored data transfers. The 8257 represents a significant savings in component count for DMA-based microcomputer systems and greatly simplifies the transfer of data at high speed between peripherals and memories.

PIN CONFIGURATION

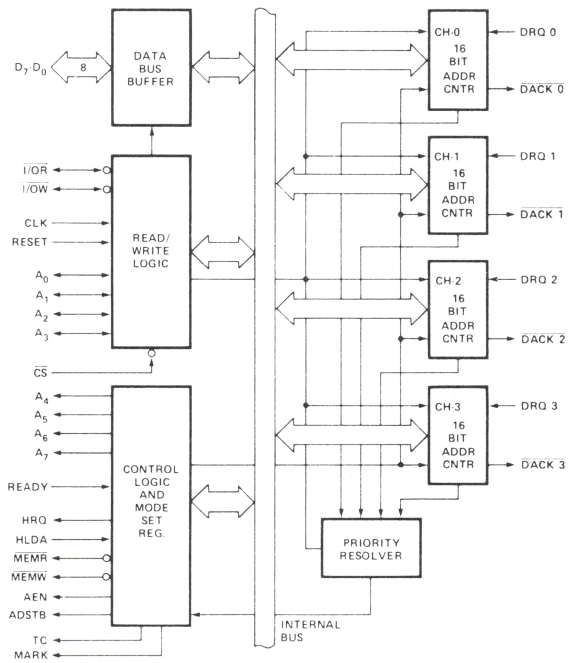


PIN NAMES

D_7-D_0	DATA BUS
A_7-A_0	ADDRESS BUS
$\overline{I/OR}$	I/O READ
$\overline{I/OW}$	I/O WRITE
$\overline{MEMR}$	MEMORY READ
$\overline{MEMW}$	MEMORY WRITE
CLK	CLOCK INPUT
RESET	RESET INPUT
READY	READY
HRQ	HOLD REQUEST (TO 8080A)
HLDA	HOLD ACKNOWLEDGE (FROM 8080A)

AEN	ADDRESS ENABLE
ADSTB	ADDRESS STROBE
TC	TERMINAL COUNT
MARK	MODULO 128 MARK
DRQ_3-DRQ_0	DMA REQUEST INPUT
$\overline{DACK_3}$-$\overline{DACK_0}$	DMA ACKNOWLEDGE OUT
$\overline{CS}$	CHIP SELECT
V_{CC}	+5 VOLTS
GND	GROUND

BLOCK DIAGRAM



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FUNCTIONAL DESCRIPTION

General

The 8257 is a programmable, Direct Memory Access (DMA) device which, when coupled with a single Intel® 8212 I/O port device, provides a complete four-channel DMA controller for use in Intel® microcomputer systems. After being initialized by software, the 8257 can transfer a block of data, containing up to 16,384 bytes, between memory and a peripheral device directly, without further intervention required of the CPU. Upon receiving a DMA transfer request from an enabled peripheral, the 8257:

1. Acquires control of the system bus.
2. Acknowledges that requesting peripheral which is connected to the highest priority channel.
3. Outputs the least significant eight bits of the memory address onto system address lines A_0-A_7, outputs the most significant eight bits of the memory address to the 8212 I/O port via the data bus (the 8212 places these address bits on lines A_8-A_{15}), and
4. Generates the appropriate memory and I/O read/write control signals that cause the peripheral to receive or deposit a data byte directly from or to the addressed location in memory.

The 8257 will retain control of the system bus and repeat the transfer sequence, as long as a peripheral maintains its DMA request. Thus, the 8257 can transfer a block of data to/from a high speed peripheral (e.g., a sector of data on a floppy disk) in a single "burst". When the specified number of data bytes have been transferred, the 8257 activates its Terminal Count (TC) output, informing the CPU that the operation is complete.

The 8257 offers three different modes of operation: (1) DMA read, which causes data to be transferred from memory to a peripheral; (2) DMA write, which causes data to be transferred from a peripheral to memory; and (3) DMA verify, which does not actually involve the transfer of data. When an 8257 channel is in the DMA verify mode, it will respond the same as described for transfer operations, except that no memory or I/O read/write control signals will be generated, thus preventing the transfer of data. The 8257, however, will gain control of the system bus and will acknowledge the peripheral's DMA request for each DMA cycle. The peripheral can use these acknowledge signals to enable an internal access of each byte of a data block in order to execute some verification procedure, such as the accumulation of a CRC (Cyclic Redundancy Code) checkword. For example, a block of DMA verify cycles might follow a block of DMA read cycles (memory to peripheral) to allow the peripheral to verify its newly acquired data.

Block Diagram Description

1. DMA Channels

The 8257 provides four separate DMA channels (labeled CH-0 to CH-3). Each channel includes two sixteen-bit registers: (1) a DMA address register, and (2) a terminal count register. Both registers must be initialized before a channel is enabled. The DMA address register is loaded with the address of the first memory location to be accessed. The value loaded into the low-order 14-bits of the terminal count register specifies the number of DMA cycles minus one before the Terminal Count (TC) output is activated. For instance, a terminal count of 0 would cause the TC output to be active in the first DMA cycle for that channel. In general, if N = the number of desired DMA cycles, load the value N-1 into the low-order 14-bits of the terminal count register. The most significant two bits of the terminal count register specify the type of DMA operation for that channel.

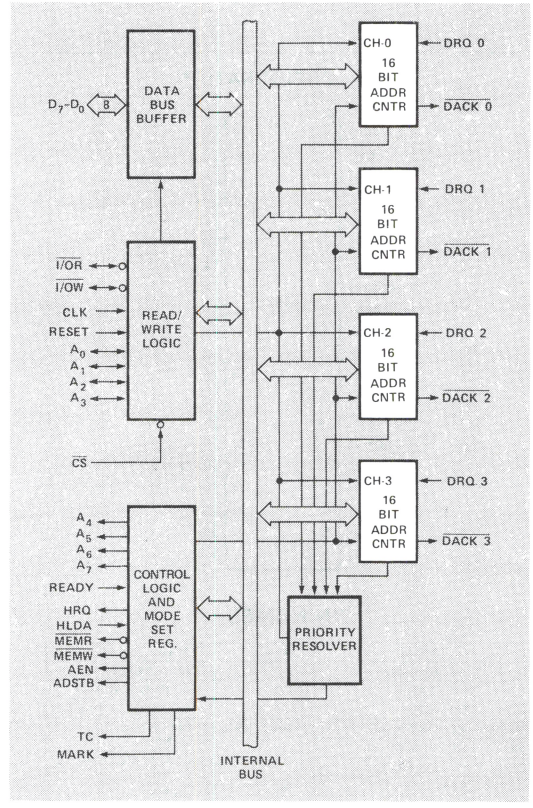


Figure 1. 8257 Block Diagram Showing DMA Channels

These two bits are not modified during a DMA cycle, but can be changed between DMA blocks.

Each channel accepts a DMA Request (DRQn) input and provides a DMA Acknowledge (DACKn) output.

(DRQ 0-DRQ 3)

DMA Request: These are individual asynchronous channel request inputs used by the peripherals to obtain a DMA cycle. If not in the rotating priority mode then DRQ 0 has the highest priority and DRQ 3 has the lowest. A request can be generated by raising the request line and holding it high until DMA acknowledge. For multiple DMA cycles (Burst Mode) the request line is held high until the DMA acknowledge of the last cycle arrives.

($\overline{\text{DACK}}$ 0 - $\overline{\text{DACK}}$ 3)

DMA Acknowledge: An active low level on the acknowledge output informs the peripheral connected to that channel that it has been selected for a DMA cycle. The $\overline{\text{DACK}}$ output acts as a "chip select" for the peripheral device requesting service. This line goes active (low) and inactive (high) once for each byte transferred even if a burst of data is being transferred.

2. Data Bus Buffer

This three-state, bi-directional, eight bit buffer interfaces the 8257 to the system data bus.

(D_0-D_7)

Data Bus Lines: These are bi-directional three-state lines. When the 8257 is being programmed by the CPU, eight-bits of data for a DMA address register, a terminal count register or the Mode Set register are received on the data bus. When the CPU reads a DMA address register, a terminal count register or the Status register, the data is sent to the CPU over the data bus. During DMA cycles (when the 8257 is the bus master), the 8257 will output the most significant eight-bits of the memory address (from one of the DMA address registers) to the 8212 latch via the data bus. These address bits will be transferred at the beginning of the DMA cycle; the bus will then be released to handle the memory data transfer during the balance of the DMA cycle.

BIT 15	BIT 14	TYPE OF DMA OPERATION
0	0	Verify DMA Cycle
0	1	Write DMA Cycle
1	0	Read DMA Cycle
1	1	(Illegal)

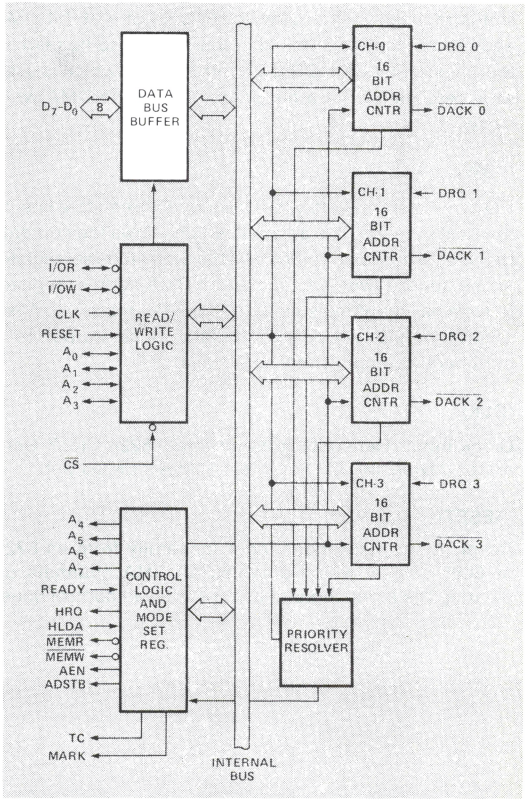


Figure 2. 8257 Block Diagram Showing Data Bus Buffer

3. Read/Write Logic

When the CPU is programming or reading one of the 8257's registers (i.e., when the 8257 is a "slave" device on the system bus), the Read/Write Logic accepts the I/O Read ($\overline{I/OR}$) or I/O Write ($\overline{I/OW}$) signal, decodes the least significant four address bits, (A_0-A_3), and either writes the contents of the data bus into the addressed register (if $\overline{I/OW}$ is true) or places the contents of the addressed register onto the data bus (if $\overline{I/OR}$ is true).

During DMA cycles (i.e., when the 8257 is the bus "master"), the Read/Write Logic generates the I/O read and memory write (DMA write cycle) or I/O Write and memory read (DMA read cycle) signals which control the data link with the peripheral that has been granted the DMA cycle.

Note that during DMA transfers Non-DMA I/O devices should be de-selected (disabled) using "AEN" signal to inhibit I/O device decoding of the memory address as an erroneous device address.

($\overline{I/OR}$)

I/O Read: An active-low, bi-directional three-state line. In the "slave" mode, it is an input which allows the 8-bit status register or the upper/lower byte of a 16-bit DMA address register or terminal count register to be read. In the "master" mode, $\overline{I/OR}$ is a control output which is used to access data from a peripheral during the DMA write cycle.

($\overline{I/OW}$)

I/O Write: An active-low, bi-directional three-state line. In the "slave" mode, it is an input which allows the contents of the data bus to be loaded into the 8-bit mode set register or the upper/lower byte of a 16-bit DMA address register or terminal count register. In the "master" mode, $\overline{I/OW}$ is a control output which allows data to be output to a peripheral during a DMA read cycle.

(CLK)

Clock Input: Generally from an Intel® 8224 Clock Generator device. (ϕ2 TTL) or Intel® 8085A CLK output.

(RESET)

Reset: An asynchronous input (generally from an 8224 or 8085 device) which disables all DMA channels by clearing the mode register and 3-states all control lines.

(A_0-A_3)

Address Lines: These least significant four address lines are bi-directional. In the "slave" mode they are inputs which select one of the registers to be read or programmed. In the "master" mode, they are outputs which constitute the least significant four bits of the 16-bit memory address generated by the 8257.

($\overline{CS}$)

Chip Select: An active-low input which enables the I/O Read or I/O Write input when the 8257 is being read or programmed in the "slave" mode. In the "master" mode, $\overline{CS}$ is automatically disabled to prevent the chip from selecting itself while performing the DMA function.

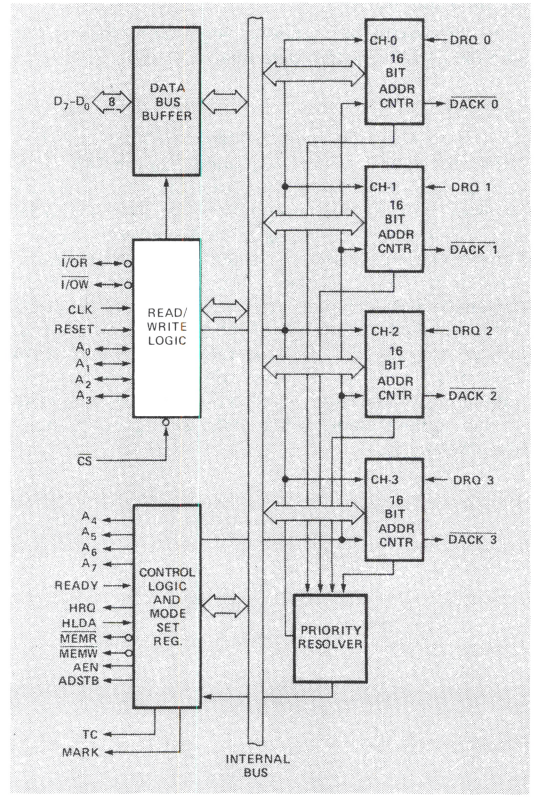


Figure 3. 8257 Block Diagram Showing Read/Write Logic Function

4. Control Logic

This block controls the sequence of operations during all DMA cycles by generating the appropriate control signals and the 16-bit address that specifies the memory location to be accessed.

(A_4-A_7)

Address Lines: These four address lines are three-state outputs which constitute bits 4 through 7 of the 16-bit memory address generated by the 8257 during all DMA cycles.

(READY)

Ready: This asynchronous input is used to elongate the memory read and write cycles in the 8257 with wait states if the selected memory requires longer cycles.

(HRQ)

Hold Request: This output requests control of the system bus. In systems with only one 8257, HRQ will normally be applied to the HOLD input on the CPU.

(HLDA)

Hold Acknowledge: This input from the CPU indicates that the 8257 has acquired control of the system bus.

($\overline{\text{MEMR}}$)

Memory Read: This active-low three-state output is used to read data from the addressed memory location during DMA Read cycles.

($\overline{\text{MEMW}}$)

Memory Write: This active-low three-state output is used to write data into the addressed memory location during DMA Write cycles.

(ADSTB)

Address Strobe: This output strobes the most significant byte of the memory address into the 8212 device from the data bus.

(AEN)

Address Enable: This output is used to disable (float) the System Data Bus and the System Control Bus. It may also be used to disable (float) the System Address Bus by use of an enable on the Address Bus drivers in systems to inhibit non-DMA devices from responding during DMA cycles. It may be further used to isolate the 8257 data bus from the System Data Bus to facilitate the transfer of the 8 most significant DMA address bits over the 8257 data I/O pins without subjecting the System Data Bus to any timing constraints for the transfer. When the 8257 is used in an I/O device structure (as opposed to memory mapped), this AEN output should be used to disable the selection of an I/O device when the DMA address is on the address bus. The I/O device selection should be determined by the DMA acknowledge outputs for the 4 channels.

(TC)

Terminal Count: This output notifies the currently selected peripheral that the present DMA cycle should be the last cycle for this data block. If the TC STOP bit in the Mode Set register is set, the selected channel will be automatically disabled at the end of that DMA cycle. TC is activated when the 14-bit value in the selected channel's terminal count register equals zero. Recall that the low-order 14-bits of the terminal count register should be loaded with the values (n-1), where n = the desired number of the DMA cycles.

(MARK)

Modulo 128 Mark: This output notifies the selected peripheral that the current DMA cycle is the 128th cycle since the previous MARK output. MARK always occurs at 128 (and all multiples of 128) cycles from the end of the data block. Only if the total number of DMA cycles (n) is evenly divisable by 128 (and the terminal count register was loaded with n-1), will MARK occur at 128 (and each succeeding multiple of 128) cycles from the beginning of the data block.

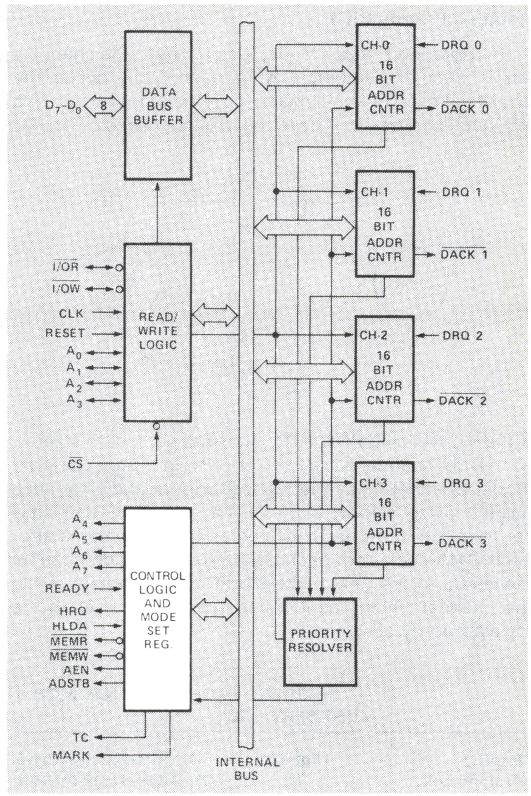
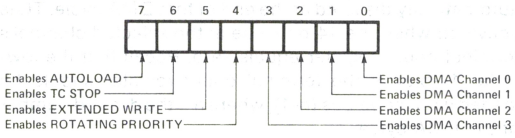


Figure 4. 8257 Block Diagram Showing Control Logic and Mode Set Register

5. Mode Set Register

When set, the various bits in the Mode Set register enable each of the four DMA channels, and allow four different options for the 8257:

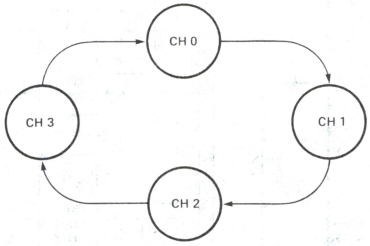


The Mode Set register is normally programmed by the CPU after the DMA address register(s) and terminal count register(s) are initialized. The Mode Set Register is cleared by the RESET input, thus disabling all options, inhibiting all channels, and preventing bus conflicts on power-up. A channel should not be left enabled unless its DMA address and terminal count registers contain valid values; otherwise, an inadvertent DMA request (DRQn) from a peripheral could initiate a DMA cycle that would destroy memory data.

The various options which can be enabled by bits in the Mode Set register are explained below:

Rotating Priority Bit 4

In the Rotating Priority Mode, the priority of the channels has a circular sequence. After each DMA cycle, the priority of each channel changes. The channel which had just been serviced will have the lowest priority.



If the ROTATING PRIORITY bit is not set (set to a zero), each DMA channel has a fixed priority. In the fixed priority mode, Channel 0 has the highest priority and Channel 3 has the lowest priority. If the ROTATING PRIORITY bit is set to a one, the priority of each channel changes after each DMA cycle (not each DMA request). Each channel moves up to the next highest priority assignment, while the channel which has just been serviced moves to the lowest priority assignment:

	CHANNEL→ JUST SERVICED	CH-0	CH-1	CH-2	CH-3
Priority → Assignments	Highest	CH-1	CH-2	CH-3	CH-0
	↑	CH-2	CH-3	CH-0	CH-1
	↓	CH-3	CH-0	CH-1	CH-2
	Lowest	CH-0	CH-1	CH-2	CH-3

Note that rotating priority will prevent any one channel from monopolizing the DMA mode; consecutive DMA cycles will service different channels if more than one channel is enabled and requesting service. There is no overhead penalty associated with this mode of operation. All DMA operations began with Channel 0 initially assigned to the highest priority for the first DMA cycle.

Extended Write Bit 5

If the EXTENDED WRITE bit is set, the duration of both the $\overline{\text{MEMW}}$ and $\overline{\text{I/OW}}$ signals is extended by activating them earlier in the DMA cycle. Data transfers within microcomputer systems proceed asynchronously to allow use of various types of memory and I/O devices with different access times. If a device cannot be accessed within a specific amount of time it returns a "not ready" indication to the 8257 that causes the 8257 to insert one or more wait states in its internal sequencing. Some devices are fast enough to be accessed without the use of wait states, but if they generate their READY response with the leading edge of the $\overline{\text{I/OW}}$ or $\overline{\text{MEMW}}$ signal (which generally occurs late in the transfer sequence), they would normally cause the 8257 to enter a wait state because it does not receive READY in time. For systems with these types of devices, the Extended Write option provides alternative timing for the I/O and memory write signals which allows the devices to return an early READY and prevents the unnecessary occurrence of wait states in the 8257, thus increasing system throughput.

TC Stop Bit 6

If the TC STOP bit is set, a channel is disabled (i.e., its enable bit is reset) after the Terminal Count (TC) output goes true, thus automatically preventing further DMA operation on that channel. The enable bit for that channel must be re-programmed to continue or begin another DMA operation. If the TC STOP bit is not set, the occurrence of the TC output has no effect on the channel enable bits. In this case, it is generally the responsibility of the peripheral to cease DMA requests in order to terminate a DMA operation.

Auto Load Bit 7

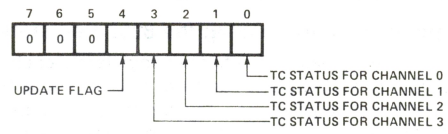
The Auto Load mode permits Channel 2 to be used for repeat block or block chaining operations, without immediate software intervention between blocks. Channel 2 registers are initialized as usual for the first data block; Channel 3 registers, however, are used to store the block re-initialization parameters (DMA starting address, terminal count and DMA transfer mode). After the first block of DMA cycles is executed by Channel 2 (i.e., after the TC output goes true), the parameters stored in the Channel 3 registers are transferred to Channel 2 during an "update" cycle. Note that the TC STOP feature, described above, has no effect on Channel 2 when the Auto Load bit is set.

If the Auto Load bit is set, the initial parameters for Channel 2 are automatically duplicated in the Channel 3 registers when Channel 2 is programmed. This permits repeat block operations to be set up with the programming of a single channel. Repeat block operations can be used in applications such as CRT refreshing. Channels 2 and 3 can still be loaded with separate values if Channel 2 is loaded before loading Channel 3. Note that in the Auto Load mode, Channel 3 is still available to the user if the Channel 3 enable bit is set, but use of this channel will change the values to be auto loaded into Channel 2 at update time. All that is necessary to use the Auto Load feature for chaining operations is to reload Channel 3 registers at the conclusion of each update cycle with the new parameters for the next data block transfer.

Each time that the 8257 enters an update cycle, the update flag in the status register is set and parameters in Channel 3 are transferred to Channel 2, non-destructively for Channel 3. The actual re-initialization of Channel 2 occurs at the beginning of the next channel 2 DMA cycle after the TC cycle. This will be the first DMA cycle of the new data block for Channel 2. The update flag is cleared at the conclusion of this DMA cycle. For chaining operations, the update flag in the status register can be monitored by the CPU to determine when the re-initialization process has been completed so that the next block parameters can be safely loaded into Channel 3.

6. Status Register

The eight-bit status register indicates which channels have reached a terminal count condition and includes the update flag described previously.



The TC status bits are set when the Terminal Count (TC) output is activated for that channel. These bits remain set until the status register is read or the 8257 is reset. The UPDATE FLAG, however, is not affected by a status register read operation. The UPDATE FLAG can be cleared by resetting the 8257, by changing to the non-auto load mode (i.e., by resetting the AUTO LOAD bit in the Mode Set register) or it can be left to clear itself at the completion of the update cycle. The purpose of the UPDATE FLAG is to prevent the CPU from inadvertently skipping a data block by overwriting a starting address or terminal count in the Channel 3 registers before those parameters are properly auto-loaded into Channel 2.

The user is cautioned against reading the TC status register and using this information to reenable channels that have not completed operation. Unless the DMA channels are inhibited a channel could reach terminal count (TC) between the status read and the mode write. DMA can be inhibited by a hardware gate on the HRQ line or by disabling channels with a mode word before reading the TC status.

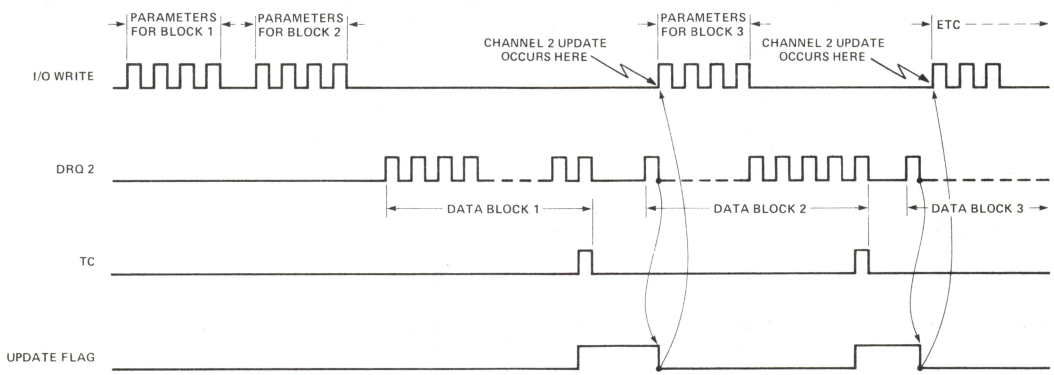


Figure 5. Autoload Timing

OPERATIONAL SUMMARY

Programming and Reading the 8257 Registers

There are four pairs of "channel registers": each pair consisting of a 16-bit DMA address register and a 16-bit terminal count register (one pair for each channel). The 8257 also includes two "general registers": one 8-bit Mode Set register and one 8-bit Status register. The registers are loaded or read when the CPU executes a write or read instruction that addresses the 8257 device and the appropriate register within the 8257. The 8228 generates the appropriate read or write control signal (generally I/OR or I/OW while the CPU places a 16-bit address on the system address bus, and either outputs the data to be written onto the system data bus or accepts the data being read from the data bus. All or some of the most significant 12 address bits A_4-A_{15} (depending on the systems memory, I/O configuration) are usually decoded to produce the chip select ($\overline{CS}$) input to the 8257. An I/O Write input (or Memory Write in memory mapped I/O configurations, described below) specifies that the addressed register is to be programmed, while an I/O Read input (or Memory Read) specifies that the addressed register is to be read. Address bit 3 specifies whether a "channel register" ($A_3 = 0$) or the Mode Set (program only)/Status (read only) register ($A_3 = 1$) is to be accessed.

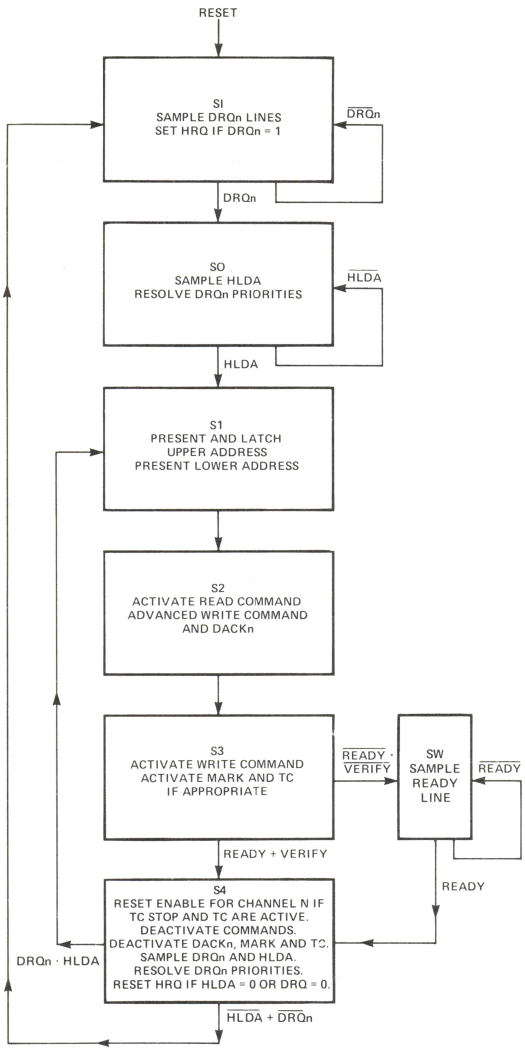
The least significant three address bits, A_0-A_2, indicate the specific register to be accessed. When accessing the Mode Set or Status register, A_0-A_2 are all zero. When accessing a channel register bit A_0 differentiates between the DMA address register ($A_0 = 0$) and the terminal count register ($A_0 = 1$), while bits A_1 and A_2 specify one of the four channels. Because the "channel registers" are 16-bits, two program instruction cycles are required to load or read an entire register. The 8257 contains a first/last (F/L) flip flop which toggles at the completion of each channel program or read operation. The F/L flip flop determines whether the upper or lower byte of the register is to be accessed. The F/L flip flop is reset by the RESET input and whenever the Mode Set register is loaded. To maintain proper synchronization when accessing the "channel registers" all channel command instruction operations should occur in pairs, with the lower byte of a register always being accessed first. Do not allow $\overline{CS}$ to clock while either $\overline{I/OR}$ or $\overline{I/OW}$ is active, as this will cause an erroneous F/L flip flop state. In systems utilizing an interrupt structure, interrupts should be disabled prior to any paired programming operations to prevent an interrupt from splitting them. The result of such a split would leave the F/L F/F in the wrong state. This problem is particularly obvious when other DMA channels are programmed by an interrupt structure.

CONTROL INPUT	$\overline{CS}$	$\overline{I/OW}$	$\overline{I/OR}$	A_3
Program Half of a Channel Register	0	0	1	0
Read Half of a Channel Register	0	1	0	0
Program Mode Set Register	0	0	1	1
Read Status Register	0	1	0	1

8257 Register Selection

REGISTER	BYTE	ADDRESS INPUTS				F/L	*BI-DIRECTIONAL DATA BUS							
		A_3	A_2	A_1	A_0		D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
CH-0 DMA Address	LSB	0	0	0	0	0	A_7	A_6	A_5	A_4	A_3	A_2	A_1	A_0
	MSB	0	0	0	0	1	A_{15}	A_{14}	A_{13}	A_{12}	A_{11}	A_{10}	A_9	A_8
CH-0 Terminal Count	LSB	0	0	0	1	0	C_7	C_6	C_5	C_4	C_3	C_2	C_1	C_0
	MSB	0	0	0	1	1	Rd	Wr	C_{13}	C_{12}	C_{11}	C_{10}	C_9	C_8
CH-1 DMA Address	LSB	0	0	1	0	0	Same as Channel 0							
	MSB	0	0	1	0	1								
CH-1 Terminal Count	LSB	0	0	1	1	0								
	MSB	0	0	1	1	1								
CH-2 DMA Address	LSB	0	1	0	0	0	Same as Channel 0							
	MSB	0	1	0	0	1								
CH-2 Terminal Count	LSB	0	1	0	1	0								
	MSB	0	1	0	1	1								
CH-3 DMA Address	LSB	0	1	1	0	0	Same as Channel 0							
	MSB	0	1	1	0	1								
CH-3 Terminal Count	LSB	0	1	1	1	0								
	MSB	0	1	1	1	1								
MODE SET (Program only)	—	1	0	0	0	0	AL	TCS	EW	RP	EN3	EN2	EN1	EN0
STATUS (Read only)	—	1	0	0	0	0	0	0	0	UP	TC3	TC2	TC1	TC0

*A_0-A_{15}: DMA Starting Address, C_0-C_{13}: Terminal Count value (N-1), Rd and Wr: DMA Verify (00), Write (01) or Read (10) cycle selection, AL: Auto Load, TCS: TC STOP, EW: EXTENDED WRITE, RP: ROTATING PRIORITY, EN3-EN0: CHANNEL ENABLE MASK, UP: UPDATE FLAG, TC3-TC0: TERMINAL COUNT STATUS BITS.



1 DRQn refers to any DRQ line on an enabled DMA channel.

Figure 6. DMA Operation State Diagram

DMA OPERATION

Single Byte Transfers

A single byte transfer is initiated by the I/O device raising the DRQ line of one channel of the 8257. If the channel is enabled, the 8257 will output a HRQ to the CPU. The 8257 now waits until a HLDA is received insuring that the system bus is free for its use. Once HLDA is received the $\overline{DACK}$ line for the requesting channel is activated (LOW). The $\overline{DACK}$ line acts as a chip select for the requesting I/O device. The 8257 then generates the read and write commands and byte transfer occurs between the selected I/O device and memory. After the transfer is complete, the $\overline{DACK}$ line is set HIGH and the HRQ line is set LOW to indicate to the CPU that the bus is now free for use. DRQ must remain HIGH until $\overline{DACK}$ is issued to be recognized and must go LOW before S4 of the transfer sequence to prevent another transfer from occuring. (See timing diagram.)

Consecutive Transfers

If more than one channel requests service simultaneously, the transfer will occur in the same way a burst does. No overhead is incurred by switching from one channel to another. In each S4 the DRQ lines are sampled and the highest priority request is recognized during the next transfer. A burst mode transfer in a lower priority channel will be overridden by a higher priority request. Once the high priority transfer has completed control will return to the lower priority channel if its DRQ is still active. No extra cycles are needed to execute this sequence and the HRQ line remains active until all DRQ lines go LOW.

Control Override

The continuous DMA transfer mode described above can be interrupted by an external device by lowering the HLDA line. After each DMA transfer the 8257 samples the HLDA line to insure that it is still active. If it is not active, the 8257 completes the current transfer, releases the HRQ line (LOW) and returns to the idle state. If DRQ lines are still active the 8257 will raise the HRQ line in the third cycle and proceed normally. (See timing diagram.)

Not Ready

The 8257 has a Ready input similar to the 8080A and the 8085A. The Ready line is sampled in State 3. If Ready is LOW the 8257 enters a wait state. Ready is sampled during every wait state. When Ready returns HIGH the 8257 proceeds to State 4 to complete the transfer. Ready is used to interface memory or I/O devices that cannot meet the bus set up times required by the 8257.

Speed

The 8257 uses four clock cycles to transfer a byte of data. No cycles are lost in the master to master transfer maximizing bus efficiency. A 2MHz clock input will allow the 8257 to transfer at a rate of 500K bytes/second.

Memory Mapped I/O Configurations

The 8257 can be connected to the system bus as a memory device instead of as an I/O device for memory mapped I/O configurations by connecting the system memory control lines to the 8257's I/O control lines and the system I/O control lines to the 8257's memory control lines.

This configuration permits use of the 8080's considerably larger repertoire of memory instructions when reading or loading the 8257's registers. Note that with this connection, the programming of the Read (bit 15) and Write (bit 14) bits in the terminal count register will have a different meaning:

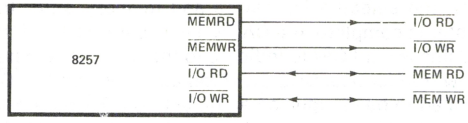


Figure 7. System Interface for Memory Mapped I/O

BIT 15 READ	BIT 14 WRITE	
0	0	DMA Verify Cycle
0	1	DMA Read Cycle
1	0	DMA Write Cycle
1	1	Illegal

Figure 8. TC Register for Memory Mapped I/O Only

SYSTEM APPLICATION EXAMPLES

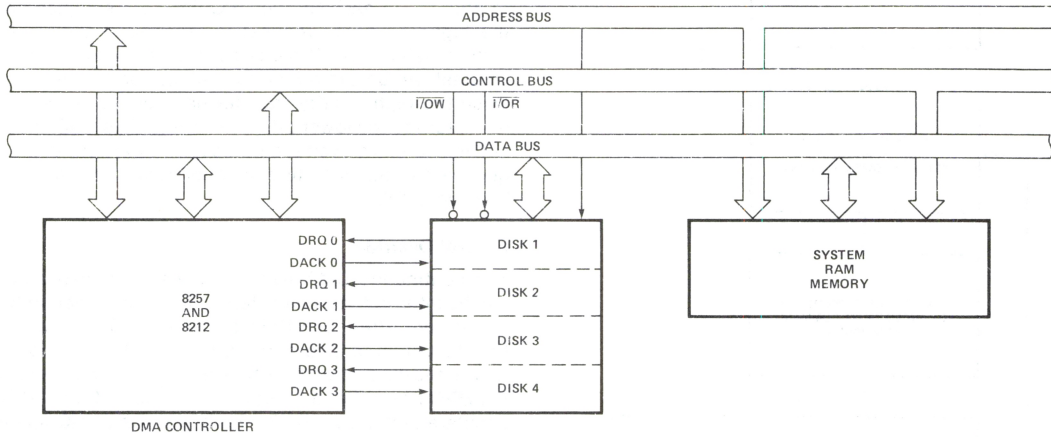


Figure 9. Floppy Disk Controller (4 Drives)

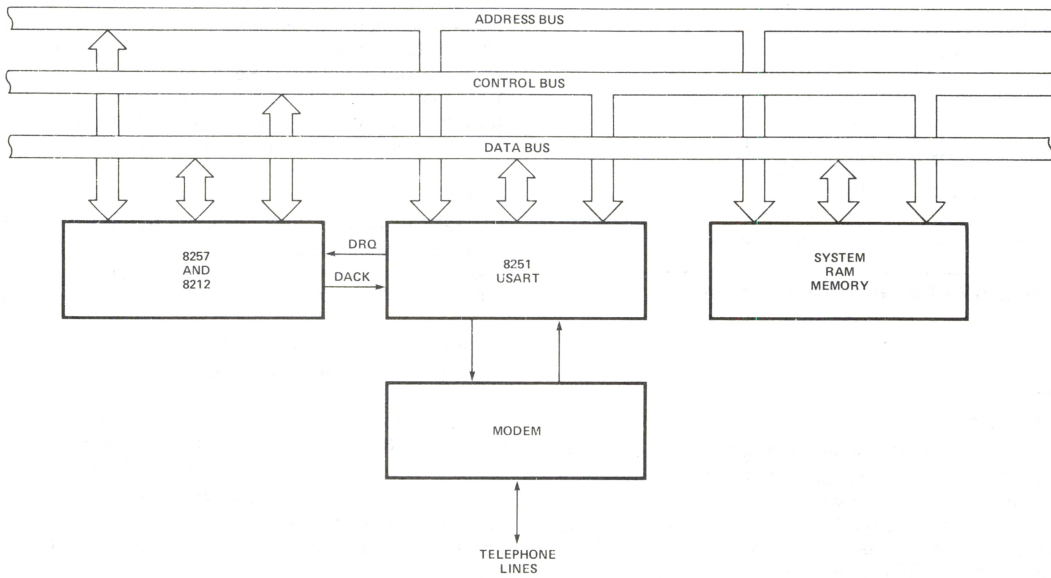


Figure 10. High-Speed Communication Controller

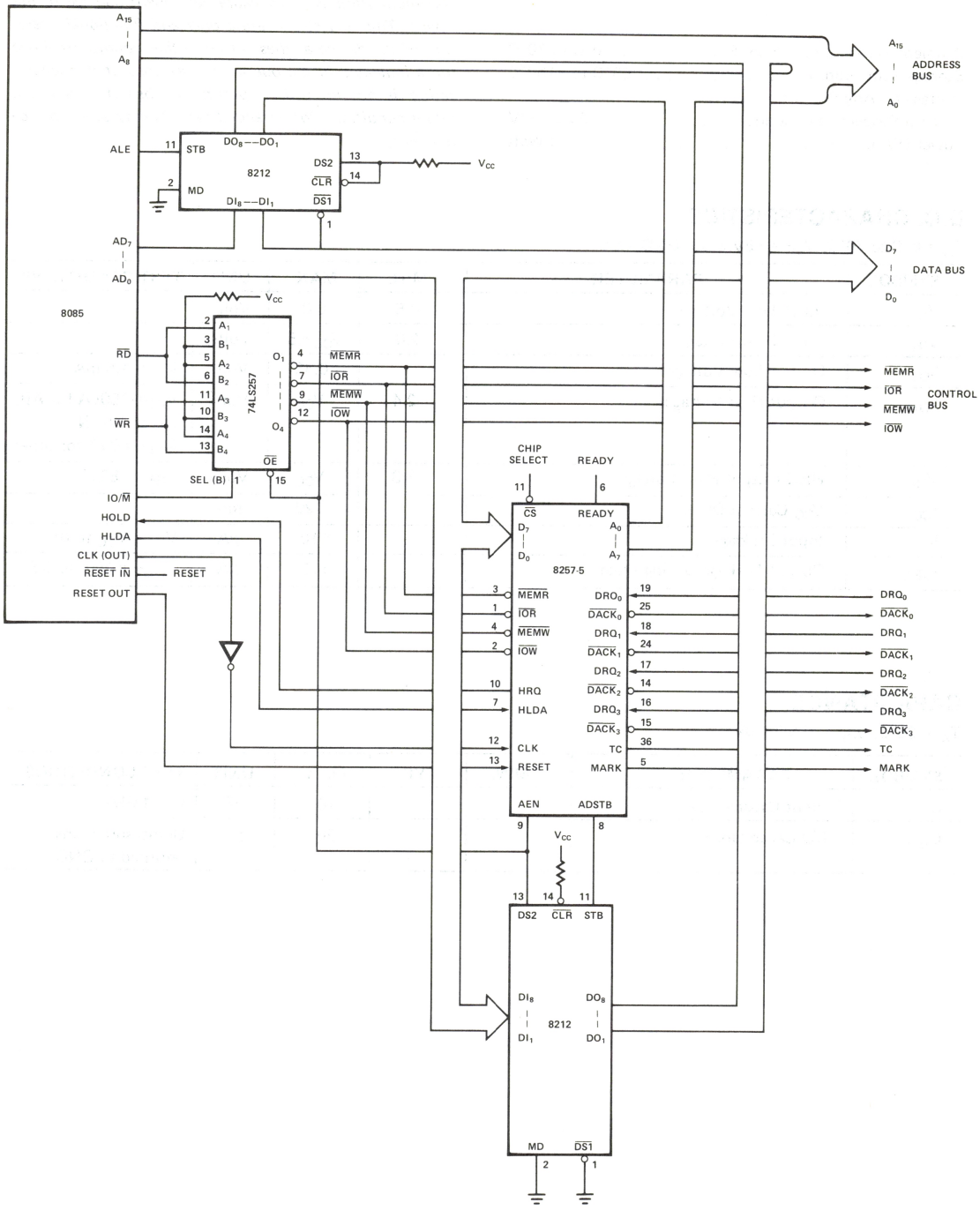


Figure 11. Detailed System Interface Schematic

ABSOLUTE MAXIMUM RATINGS*

Ambient Temperature Under Bias. . . . . 0°C to 70°C
Storage Temperature . . . . . –65°C to +150°C
Voltage on Any Pin
With Respect to Ground . . . . . –0.5V to +7V
Power Dissipation . . . . . 1 Watt

**COMMENT: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

D.C. CHARACTERISTICS

T_A = 0°C to 70°C, V_{CC} = +5V ± 5%, GND = 0V

SYMBOL	PARAMETER	MIN.	MAX.	UNIT	TEST CONDITIONS
V_{IL}	Input Low Voltage	-0.5	0.8	Volts	
V_{IH}	Input High Voltage	2.0	V_{CC}+.5	Volts	
V_{OL}	Output Low Voltage		0.45	Volts	I_{OL} = 1.6 mA
V_{OH}	Output High Voltage	2.4	V_{CC}	Volts	I_{OH}=-150μA for AB, DB and AEN I_{OH}=-80μA for others
V_{HH}	HRQ Output High Voltage	3.3	V_{CC}	Volts	I_{OH} = -80μA
I_{CC}	V_{CC} Current Drain		120	mA	
I_{IL}	Input Leakage		±10	μA	V_{IN} = V_{CC} to 0V
I_{OFL}	Output Leakage During Float		±10	μA	V_{OUT} = V_{CC} to 0V

CAPACITANCE

T_A = 25°C; V_{CC} = GND = 0V

SYMBOL	PARAMETER	MIN.	TYP.	MAX.	UNIT	TEST CONDITIONS
C_{IN}	Input Capacitance			10	pF	fc = 1MHz
$C_{I/O}$	I/O Capacitance			20	pF	Unmeasured pins returned to GND

A.C. CHARACTERISTICS: PERIPHERAL (SLAVE) MODE

T_A = 0°C to 70°C, V_{CC} = 5.0V ±5%; GND = 0V (Note 1).

8080 Bus Parameters

Read Cycle:

Symbol	Parameter	8257 Min.	8257 Max.	8257-5 Min.	8257-5 Max.	Unit	Test Conditions
T_{AR}	Adr or $\overline{CS}\downarrow$ Setup to $\overline{RD}\downarrow$	0		0		ns	
T_{RA}	Adr or $\overline{CS}\uparrow$ Hold from $\overline{RD}\uparrow$	0		0		ns	
T_{RD}	Data Access from $\overline{RD}\downarrow$	0	300	0	200	ns	(Note 2)
T_{DF}	DB→Float Delay from $\overline{RD}\uparrow$	20	150	20	100	ns	
T_{RR}	$\overline{RD}$ Width	250		250		ns	

Write Cycle:

Symbol	Parameter	8257 Min.	8257 Max.	8257-5 Min.	8257-5 Max.	Unit	Test Conditions
T_{AW}	Adr Setup to $\overline{WR}\downarrow$	20		20		ns	
T_{WA}	Adr Hold from $\overline{WR}\uparrow$	0		0		ns	
T_{DW}	Data Setup to $\overline{WR}\uparrow$	200		200		ns	
T_{WD}	Data Hold from $\overline{WR}\uparrow$	0		0		ns	
T_{WW}	$\overline{WR}$ Width	200		200		ns	

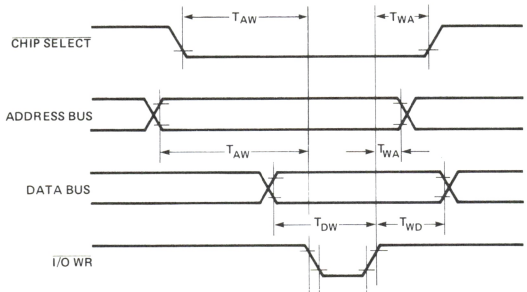
Other Timing:

Symbol	Parameter	8257 Min.	8257 Max.	8257-5 Min.	8257-5 Max.	Unit	Test Conditions
T_{RSTW}	Reset Pulse Width	300		300		ns	
T_{RSTD}	Power Supply↑ (V_{CC}) Setup to Reset↓	500		500		μs	
T_r	Signal Rise Time		20		20	ns	
T_f	Signal Fall Time		20		20	ns	
T_{RSTS}	Reset to First $\overline{I/O}\overline{WR}$	2		2		t_{CY}	

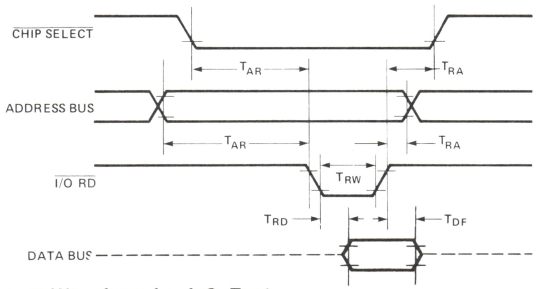
Notes: 1. All timing measurements are made at the following reference voltages unless specified otherwise: Input "1" at 2.0V, "0" at 0.8V
Output "1" at 2.0V, "0" at 0.8V
2. 8257: C_L = 100pF, 8257-5: C_L = 150pF.

8257 PERIPHERAL MODE TIMING DIAGRAMS

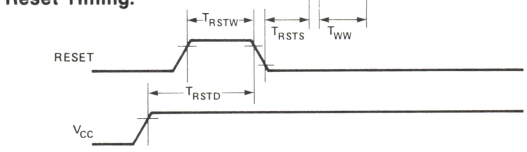
Write Timing:



Read Timing:



Reset Timing:



Input Waveform for A.C. Tests:



A.C. CHARACTERISTICS: DMA (MASTER) MODE $T_A = 0°C$ to $70°C$, $V_{CC} = +5V \pm 5\%$, GND = 0V

Timing Requirements

SYMBOL	PARAMETER	8257		8257-5		UNIT
		MIN.	MAX.	MIN.	MAX.	
T_{CY}	Cycle Time (Period)	0.320	4	0.320	4	μs
T_θ	Clock Active (High)	120	$.8T_{CY}$	80	$.8T_{CY}$	ns
T_{QS}	DRQ↑ Setup to θ↓ (SI, S4)	120		120		ns
T_{QH}	DRQ↓ Hold from HLDA↑[4]	0		0		ns
T_{HS}	HLDA↑ or ↓Setup to θ↓(SI, S4)	100		100		ns
T_{RS}	READY Setup Time to θ↑ (S3, Sw)	30		30		ns
T_{RH}	READY Hold Time from θ↑ (S3, Sw)	20		20		ns

Note: 4. Tracking Parameter.

Tracking Parameters

Signals labeled as Tracking Parameters (footnotes 4-7 under A.C. Specifications) are signals that follow similar paths through the silicon die. The propagation speed of these signals varies in the manufacturing process but the relationship between all these parameters is constant. The variation is less than or equal to 50 ns.

Suppose the following timing equation is being evaluated,

$$T_{A(MIN)} + T_{B(MAX)} \leq 150 \text{ ns}$$

and only minimum specifications exist for T_A and T_B. If $T_{A(MIN)}$ is used, and if T_A and T_B are tracking parameters, $T_{B(MAX)}$ can be taken as $T_{B(MIN)} + 50$ ns.

$$T_{A(MIN)} + (T_{B(MIN)}^* + 50 \text{ ns}) \leq 150 \text{ ns}$$

*if T_A and T_B are tracking parameters

A.C. CHARACTERISTICS: DMA (MASTER) MODE $T_A = 0°C$ to $70°C$, $V_{CC} = +5V \pm 5\%$, GND = 0V

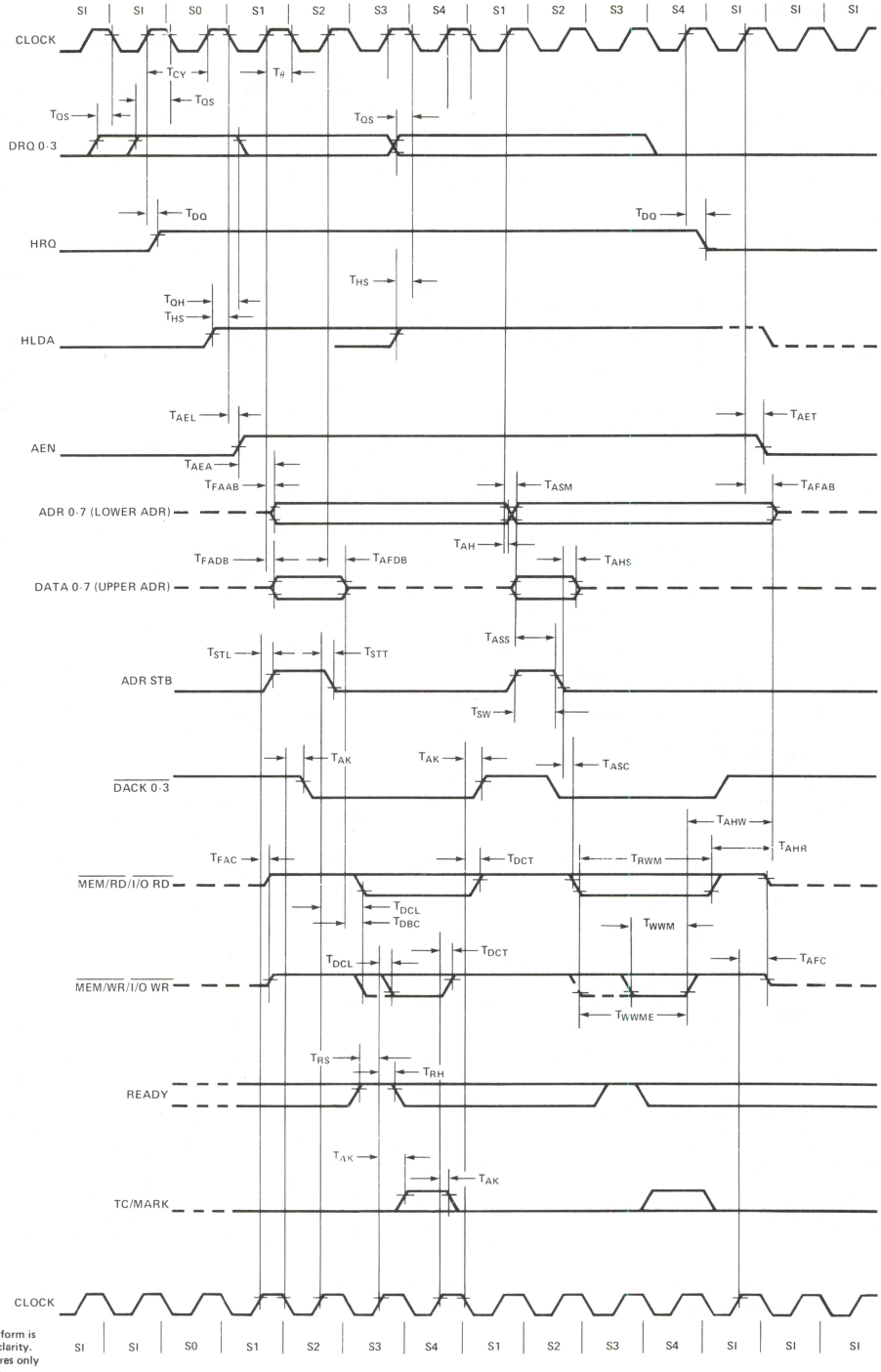
Timing Responses

SYMBOL	PARAMETER	8257		8257-5		UNIT
		MIN.	MAX.	MIN.	MAX.	
T_{DQ}	HRQ↑ or ↓Delay from θ↑(SI,S4) (measured at 2.0V)[1]		160		160	ns
T_{DQ1}	HRQ↑ or ↓Delay from θ↑(SI,S4) (measured at 3.3V)[3]		250		250	ns
T_{AEL}	AEN↑ Delay from θ↓(S1)[1]		300		300	ns
T_{AET}	AEN↓ Delay from θ↑(SI)[1]		200		200	ns
T_{AEA}	Adr(AB)(Active) Delay from AEN↑(S1)[4]	20		20		ns
T_{FAAB}	Adr(AB)(Active) Delay from θ↑(S1)[2]		250		250	ns
T_{AFAB}	Adr(AB)(Float) Delay from θ↑(SI)[2]		150		150	ns
T_{ASM}	Adr(AB)(Stable) Delay from θ↑(S1)[2]		250		250	ns
T_{AH}	Adr(AB)(Stable) Hold from θ↑(S1)[2]	T_{ASM}-50		T_{ASM}-50		ns
T_{AHR}	Adr(AB)(Valid) Hold from $\overline{Rd}$↑(S1,SI)[4]	60		60		ns
T_{AHW}	Adr(AB)(Valid) Hold from $\overline{Wr}$↑(S1,SI)[4]	300		300		ns
T_{FADB}	Adr(DB)(Active) Delay from θ↑(S1)[2]		300		300	ns
T_{AFDB}	Adr(DB)(Float) Delay from θ↑(S2)[2]	T_{STT}+20	250	T_{STT}+20	170	ns
T_{ASS}	Adr(DB) Setup to AdrStb↓(S1-S2)[4]	100		100		ns
T_{AHS}	Adr(DB)(Valid) Hold from AdrStb↓(S2)[4]	50		50		ns
T_{STL}	AdrStb↑ Delay from θ↑(S1)[1]		200		200	ns
T_{STT}	AdrStb↓ Delay from θ↑(S2)[1]		140		140	ns
T_{SW}	AdrStb Width (S1-S2)[4]	T_{CY}-100		T_{CY}-100		ns
T_{ASC}	$\overline{Rd}$↓ or $\overline{Wr}$(Ext)↓ Delay from AdrStb↓(S2)[4]	70		70		ns
T_{DBC}	$\overline{Rd}$↓ or $\overline{Wr}$(Ext)↓ Delay from Adr(DB) (Float)(S2)[4]	20		20		ns
T_{AK}	DACK↑ or ↓Delay from θ↓(S2,S1) and TC/Mark↑ Delay from θ↑(S3) and TC/Mark↓ Delay from θ↑(S4)[1,5]		250		250	ns
T_{DCL}	$\overline{Rd}$↓ or $\overline{Wr}$(Ext)↓ Delay from θ↑(S2) and $\overline{Wr}$↓ Delay from θ↑(S3)[2,6]		200		200	ns
T_{DCT}	$\overline{Rd}$↑ Delay from θ↓(S1,SI) and $\overline{Wr}$↑ Delay from θ↑(S4)[2,7]		200		200	ns
T_{FAC}	$\overline{Rd}$ or $\overline{Wr}$ (Active) from θ↑(S1)[2]		300		300	ns
T_{AFC}	$\overline{Rd}$ or $\overline{Wr}$ (Float) from θ↑(SI)[2]		150		150	ns
T_{RWM}	$\overline{Rd}$ Width (S2-S1 or SI)[4]	$2T_{CY} + T_\theta$-50		$2T_{CY} + T_\theta$-50		ns
T_{WWM}	$\overline{Wr}$ Width (S3-S4)[4]	T_{CY}-50		T_{CY}-50		ns
T_{WWME}	$\overline{Wr}$(Ext) Width (S2-S4)[4]	$2T_{CY}$-50		$2T_{CY}$-50		ns

Notes: 1. Load = 1 TTL. 2. Load = 1 TTL + 50pF. 3. Load = 1 TTL + (R_L = 3.3K), V_{OH} = 3.3V. 4. Tracking Parameter.
5. $\Delta T_{AK} < 50$ ns. 6. $\Delta T_{DCL} < 50$ ns. 7. $\Delta T_{DCT} < 50$ ns.

DMA MODE WAVEFORMS

CONSECUTIVE CYCLES AND BURST MODE SEQUENCE



NOTE: The clock waveform is duplicated for clarity. The 8257 requires only one clock input.

Figure 12. Consecutive Cycles and Burst Mode Sequence

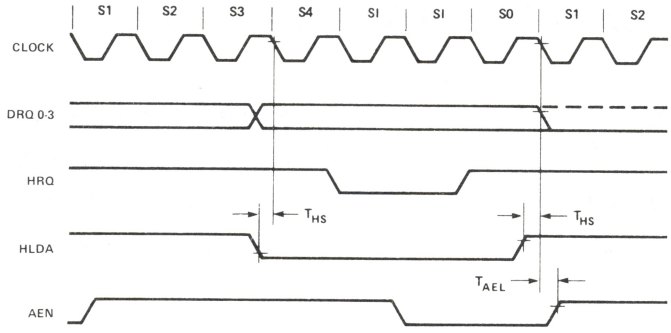


Figure 13. Control Override Sequence

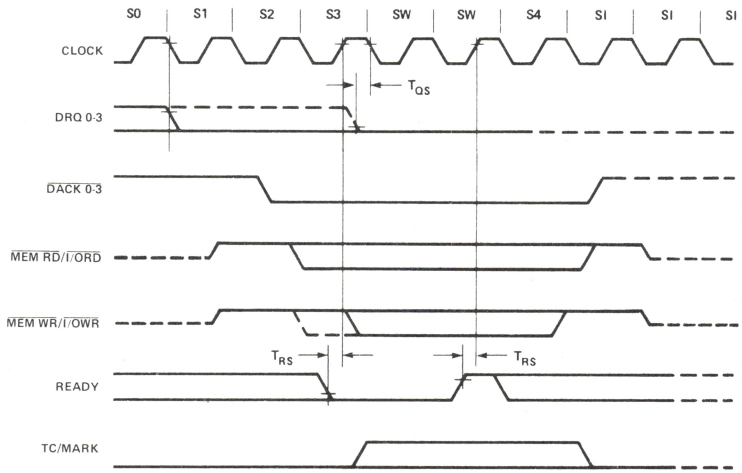


Figure 14. Not Ready Sequence

PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

8259A/8259A-2/8259A-8
PROGRAMMABLE INTERRUPT CONTROLLER

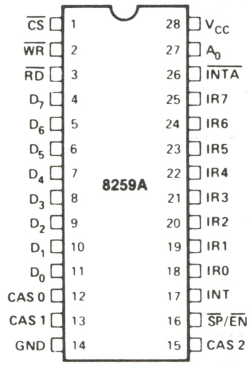
- 8086/8088 Compatible
- MCS-80/85™ Compatible
- Eight-Level Priority Controller
- Expandable to 64 Levels
- Programmable Interrupt Modes
- Individual Request Mask Capability
- Single +5V Supply (No Clocks)
- 28-Pin Dual-In-Line Package

The Intel® 8259A Programmable Interrupt Controller handles up to eight vectored priority interrupts for the CPU. It is cascadable for up to 64 vectored priority interrupts without additional circuitry. It is packaged in a 28-pin DIP, uses NMOS technology and requires a single +5V supply. Circuitry is static, requiring no clock input.

The 8259A is designed to minimize the software and real time overhead in handling multi-level priority interrupts. It has several modes, permitting optimization for a variety of system requirements.

The 8259A is fully upward compatible with the Intel® 8259. Software originally written for the 8259 will operate the 8259A in all 8259 equivalent modes (MCS-80/85, Non-Buffered, Edge Triggered).

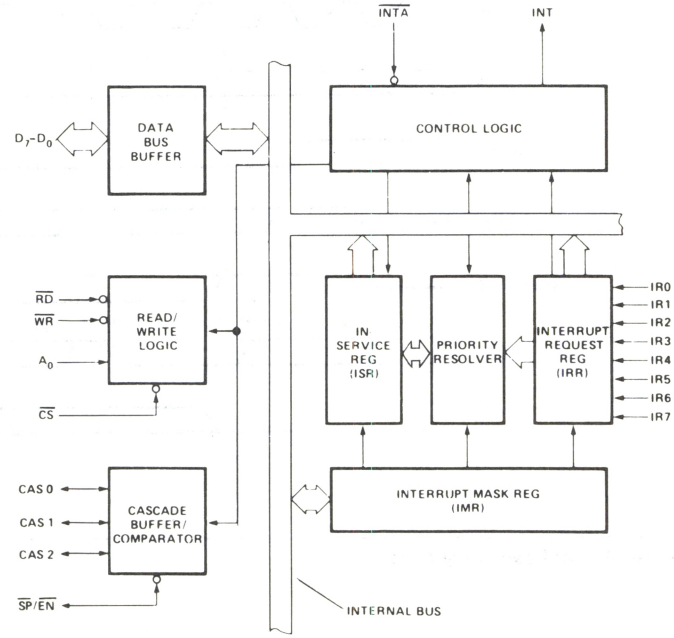
PIN CONFIGURATION



PIN NAMES

D_7-D_0	DATA BUS (BI-DIRECTIONAL)
$\overline{RD}$	READ INPUT
$\overline{WR}$	WRITE INPUT
A_0	COMMAND SELECT ADDRESS
$\overline{CS}$	CHIP SELECT
CAS2-CAS0	CASCADE LINES
$\overline{SP}/\overline{EN}$	SLAVE PROGRAM/ENABLE BUFFER
INT	INTERRUPT OUTPUT
$\overline{INTA}$	INTERRUPT ACKNOWLEDGE INPUT
IR0-IR7	INTERRUPT REQUEST INPUTS

BLOCK DIAGRAM



PRELIMINARY
Notice: This is not a final specification. Some parameters are subject to change.

INTERRUPTS IN MICROCOMPUTER SYSTEMS

Microcomputer system design requires that I/O devices such as keyboards, displays, sensors and other components receive servicing in an efficient manner so that large amounts of the total system tasks can be assumed by the microcomputer with little or no effect on throughput.

The most common method of servicing such devices is the *Polled* approach. This is where the processor must test each device in sequence and in effect "ask" each one if it needs servicing. It is easy to see that a large portion of the main program is looping through this continuous polling cycle and that such a method would have a serious, detrimental effect on system throughput, thus limiting the tasks that could be assumed by the microcomputer and reducing the cost effectiveness of using such devices.

A more desirable method would be one that would allow the microprocessor to be executing its main program and only stop to service peripheral devices when it is told to do so by the device itself. In effect, the method would provide an external asynchronous input that would inform the processor that it should complete whatever instruction that is currently being executed and fetch a new routine that will service the requesting device. Once this servicing is complete, however, the processor would resume exactly where it left off.

This method is called *Interrupt*. It is easy to see that system throughput would drastically increase, and thus more tasks could be assumed by the microcomputer to further enhance its cost effectiveness.

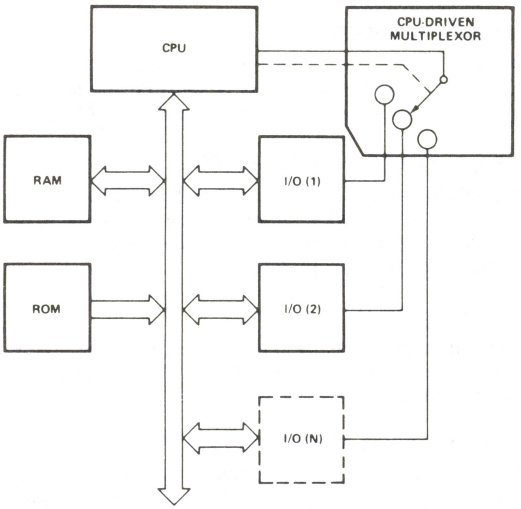
The Programmable Interrupt Controller (PIC) functions as an overall manager in an Interrupt-Driven system environment. It accepts requests from the peripheral equipment, determines which of the incoming requests is of the highest importance (priority), ascertains whether the incoming request has a higher priority value than the level currently being serviced, and issues an interrupt to the CPU based on this determination.

Each peripheral device or structure usually has a special program or "routine" that is associated with its specific functional or operational requirements; this is referred to as a "service routine". The PIC, after issuing an Interrupt to the CPU, must somehow input information into the CPU that can "point" the Program Counter to the service routine associated with the requesting device. This "pointer" is an address in a vectoring table and will often be referred to, in this document, as vectoring data.

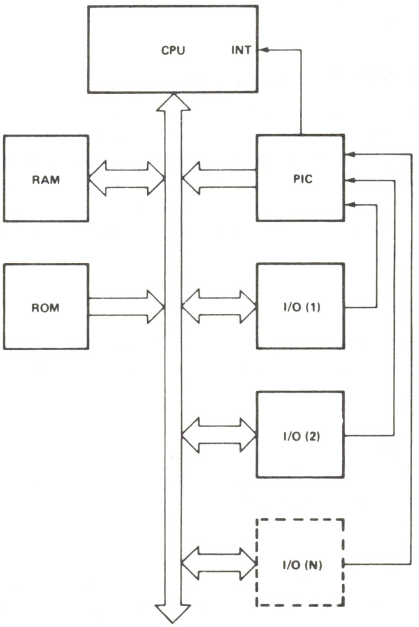
8259A BASIC FUNCTIONAL DESCRIPTION

GENERAL

The 8259A is a device specifically designed for use in real time, interrupt driven microcomputer systems. It manages eight levels or requests and has built-in features for expandability to other 8259A's (up to 64 levels). It is programmed by the system's software as an I/O peripheral. A selection of priority modes is available to the programmer so that the manner in which the requests are processed by the 8259A can be configured to match his system requirements. The priority modes can be changed or reconfigured dynamically at any time during the main program. This means that the complete interrupt structure can be defined as required, based on the total system environment.



Polled Method



Interrupt Method

PRELIMINARY
Notice: This is not a final specification. Some parameter limits are subject to change.

INTERRUPT REQUEST REGISTER (IRR) AND IN-SERVICE REGISTER (ISR)

The interrupts at the IR input lines are handled by two registers in cascade, the Interrupt Request Register (IRR) and the In-Service Register (ISR). The IRR is used to store all the interrupt levels which are requesting service; and the ISR is used to store all the interrupt levels which are being serviced.

PRIORITY RESOLVER

This logic block determines the priorities of the bits set in the IRR. The highest priority is selected and strobed into the corresponding bit of the ISR during $\overline{INTA}$ pulse.

INTERRUPT MASK REGISTER (IMR)

The IMR stores the bits which mask the interrupt lines to be masked. The IMR operates on the IRR. Masking of a higher priority input will not affect the interrupt request lines of lower priority.

INT (INTERRUPT)

This output goes directly to the CPU interrupt input. The V_{OH} level on this line is designed to be fully compatible with the 8080A, 8085A, 8086 and 8088.

$\overline{INTA}$ (INTERRUPT ACKNOWLEDGE)

$\overline{INTA}$ pulses will cause the 8259A to release vectoring information onto the data bus. The format of this data depends on the system mode (μPM) of the 8259A.

DATA BUS BUFFER

This 3-state, bidirectional 8-bit buffer is used to interface the 8259A to the system Data Bus. Control words and status information are transferred through the Data Bus Buffer.

READ/WRITE CONTROL LOGIC

The function of this block is to accept OUTput commands from the CPU. It contains the Initialization Command Word (ICW) registers and Operation Command Word (OCW) registers which store the various control formats for device operation. This function block also allows the status of the 8259A to be transferred onto the Data Bus.

$\overline{CS}$ (CHIP SELECT)

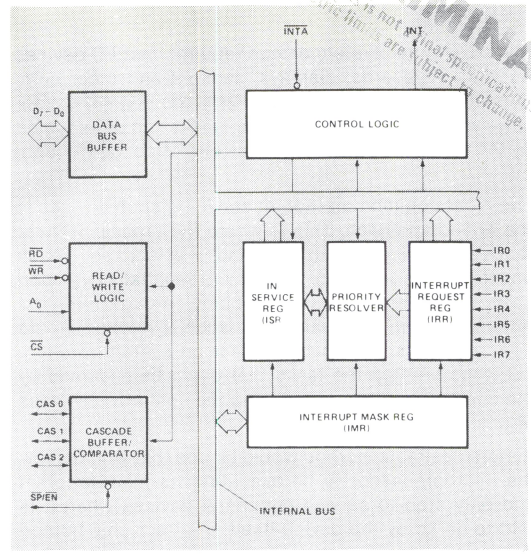
A LOW on this input enables the 8259A. No reading or writing of the chip will occur unless the device is selected.

$\overline{WR}$ (WRITE)

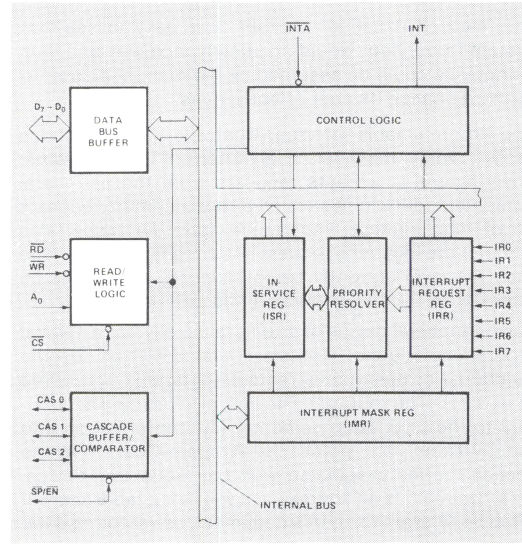
A LOW on this input enables the CPU to write control words (ICWs and OCWs) to the 8259A.

$\overline{RD}$ (READ)

A LOW on this input enables the 8259A to send the status of the Interrupt Request Register (IRR), In Service Register (ISR), the Interrupt Mask Register (IMR), or the Interrupt level onto the Data Bus.



8259A Block Diagram



8259A Block Diagram

A_0

This input signal is used in conjunction with $\overline{WR}$ and $\overline{RD}$ signals to write commands into the various command registers, as well as reading the various status registers of the chip. This line can be tied directly to one of the address lines.

PRELIMINARY
Notice: This is not a final specification. Some parameter limits are subject to change.

THE CASCADE BUFFER/COMPARATOR

This function block stores and compares the IDs of all 8259A's used in the system. The associated three I/O pins (CAS0-2) are outputs when the 8259A is used as a master and are inputs when the 8259A is used as a slave. As a master, the 8259A sends the ID of the interrupting slave device onto the CAS0-2 lines. The slave thus selected will send its preprogrammed subroutine address onto the Data Bus during the next one or two consecutive $\overline{INTA}$ pulses. (See section "Cascading the 8259A".)

INTERRUPT SEQUENCE

The powerful features of the 8259A in a microcomputer system are its programmability and the interrupt routine addressing capability. The latter allows direct or indirect jumping to the specific interrupt routine requested without any polling of the interrupting devices. The normal sequence of events during an interrupt depends on the type of CPU being used.

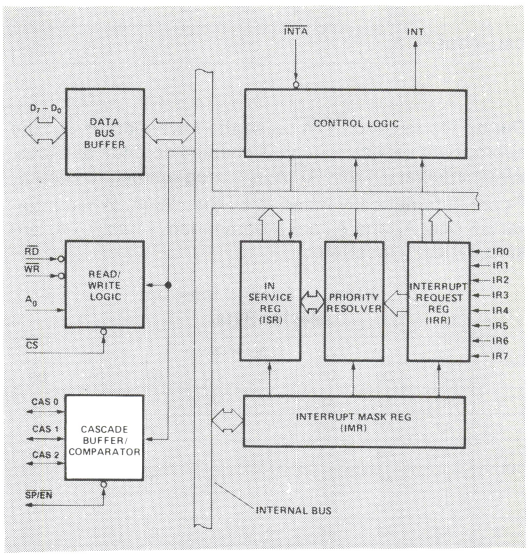
The events occur as follows in an MCS-80/85 system:

1. One or more of the INTERRUPT REQUEST lines (IR7-0) are raised high, setting the corresponding IRR bit(s).
2. The 8259A evaluates these requests, and sends an INT to the CPU, if appropriate.
3. The CPU acknowledges the INT and responds with an $\overline{INTA}$ pulse.
4. Upon receiving an $\overline{INTA}$ from the CPU group, the highest priority ISR bit is set, and the corresponding IRR bit is reset. The 8259A will also release a CALL instruction code (11001101) onto the 8-bit Data Bus through its D7-0 pins.
5. This CALL instruction will initiate two more $\overline{INTA}$ pulses to be sent to the 8259A from the CPU group.
6. These two $\overline{INTA}$ pulses allow the 8259A to release its preprogrammed subroutine address onto the Data Bus. The lower 8-bit address is released at the first $\overline{INTA}$ pulse and and the higher 8-bit address is released at the second $\overline{INTA}$ pulse.
7. This completes the 3-byte CALL instruction released by the 8259A. In the AEOI mode the ISR bit is reset at the end of the third $\overline{INTA}$ pulse. Otherwise, the ISR bit remains set until an appropriate EOI command is issued at the end of the interrupt sequence.

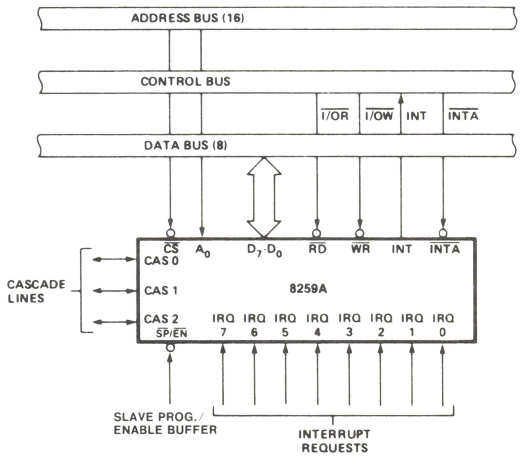
The events occuring in an 8086/8088 system are the same until step 4.

4. Upon receiving an $\overline{INTA}$ from the CPU group, the highest priority ISR bit is set and the corresponding IRR bit is reset. The 8259A does not drive the Data Bus during this cycle.
5. The 8086/8088 CPU will initiate a second $\overline{INTA}$ pulse. During this pulse, the 8259A releases an 8-bit pointer onto the Data Bus where it is read by the CPU.
6. This completes the interrupt cycle. In the AEOI mode the ISR bit is reset at the end of the second $\overline{INTA}$ pulse. Otherwise, the ISR bit remains set until an appropriate EOI command is issued at the end of the interrupt subroutine.

If no interrupt request is present at step 4 of either sequence (i.e., the request was too short in duration) the 8259A will issue an interrupt level 7. Both the vectoring bytes and the CAS lines will look like an interrupt level 7 was requested.



8259A Block Diagram



8259A Interface to Standard System Bus

PRELIMINARY
Nation's products are subject to change.

INTERRUPT SEQUENCE OUTPUTS

MCS-80/85 MODE

This sequence is timed by three $\overline{INTA}$ pulses. During the first $\overline{INTA}$ pulse the CALL opcode is enabled onto the data bus.

Content of First Interrupt Vector Byte

	D7	D6	D5	D4	D3	D2	D1	D0
CALL CODE	1	1	0	0	1	1	0	1

During the second $\overline{INTA}$ pulse the lower address of the appropriate service routine is enabled onto the data bus. When Interval = 4 bits A_5-A_7 are programmed, while A_0-A_4 are automatically inserted by the 8259A. When Interval = 8 only A_6 and A_7 are programmed, while A_0-A_5 are automatically inserted.

Content of Second Interrupt Vector Byte

IR	Interval = 4							
	D7	D6	D5	D4	D3	D2	D1	D0
7	A7	A6	A5	1	1	1	0	0
6	A7	A6	A5	1	1	0	0	0
5	A7	A6	A5	1	0	1	0	0
4	A7	A6	A5	1	0	0	0	0
3	A7	A6	A5	0	1	1	0	0
2	A7	A6	A5	0	1	0	0	0
1	A7	A6	A5	0	0	1	0	0
0	A7	A6	A5	0	0	0	0	0

IR	Interval = 8							
	D7	D6	D5	D4	D3	D2	D1	D0
7	A7	A6	1	1	1	0	0	0
6	A7	A6	1	1	0	0	0	0
5	A7	A6	1	0	1	0	0	0
4	A7	A6	1	0	0	0	0	0
3	A7	A6	0	1	1	0	0	0
2	A7	A6	0	1	0	0	0	0
1	A7	A6	0	0	1	0	0	0
0	A7	A6	0	0	0	0	0	0

During the third INTA pulse the higher address of the appropriate service routine, which was programmed as byte 2 of the initialization sequence (A_8 – A_{15}), is enabled onto the bus.

Content of Third Interrupt Vector Byte

D7	D6	D5	D4	D3	D2	D1	D0
A15	A14	A13	A12	A11	A10	A9	A8

8086/8088 Mode

8086/8088 mode is similar to MCS80/85 mode except that only two Interrupt Acknowledge cycles are issued by the processor and no CALL opcode is sent to the processor. The first interrupt acknowledge cycle is similar to that of MCS-80/85 systems in that the 8259A uses it to internally freeze the state of the interrupts for priority resolution and as a master it issues the interrupt code on the cascade lines at the end of the $\overline{INTA}$ pulse. On this first cycle it does not issue any data to the processor and leaves its data bus buffers disabled. On the second interrupt acknowledge cycle in 8086/8088 mode the master (or slave if so programmed) will send a byte of data to the processor with the acknowledged interrupt code composed as follows (note the state of the ADI mode control is ignored and A_5-A_{11} are unused in 8086/8088 mode):

	D7	D6	D5	D4	D3	D2	D1	D0
IR7	T7	T6	T5	T4	T3	1	1	1
IR6	T7	T6	T5	T4	T3	1	1	0
IR5	T7	T6	T5	T4	T3	1	0	1
IR4	T7	T6	T5	T4	T3	1	0	0
IR3	T7	T6	T5	T4	T3	0	1	1
IR2	T7	T6	T5	T4	T3	0	1	0
IR1	T7	T6	T5	T4	T3	0	0	1
IR0	T7	T6	T5	T4	T3	0	0	0

PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

PROGRAMMING THE 8259A

The 8259A accepts two types of command words generated by the CPU:

1. *Initialization Command Words (ICWs):* Before normal operation can begin, each 8259A in the system must be brought to a starting point — by a sequence of 2 to 4 bytes timed by $\overline{WR}$ pulses. This sequence is described in Figure 1.

2. *Operation Command Words (OCWs):* These are the command words that are sent to the 8259A for various forms of operation, such as:

- Interrupt Masking
- End of Interrupt
- Priority Rotation
- Interrupt Status

The OCWs can be written into the 8259A anytime after initialization.

INITIALIZATION

GENERAL

Whenever a command is issued with A0=0 and D4=1, this is interpreted as Initialization Command Word 1 (ICW1). ICW1 starts the initialization sequence during which the following automatically occur.

a. The edge sense circuit is reset, which means that following initialization, an interrupt request (IR) input must make a low-to-high transition to generate an interrupt.
b. The Interrupt Mask Register is cleared.
c. R7 input is assigned priority 7.
d. The slave mode address is set to 7.
e. Special Mask Mode is cleared and Status Read is set to IRR.
f. If IC4=0, then all functions selected in ICW4 are set to zero. (Non-Buffered mode*, no Auto-EOI, MCS-80/85 system).

*Note: Master/Slave in ICW4 is only used in the buffered mode.

A_0	D_4	D_3	$\overline{RD}$	$\overline{WR}$	$\overline{CS}$	INPUT OPERATION (READ)
0			0	1	0	IRR, ISR or Interrupting Level → DATA BUS (Note 1)
1			0	1	0	IMR → DATA BUS
						OUTPUT OPERATION (WRITE)
0	0	0	1	0	0	DATA BUS → OCW2
0	0	1	1	0	0	DATA BUS → OCW3
0	1	X	1	0	0	DATA BUS → ICW1
1	X	X	1	0	0	DATA BUS → OCW1, ICW2, ICW3, ICW4 (Note 2)
						DISABLE FUNCTION
X	X	X	1	1	0	DATA BUS — 3-STATE (NO OPERATION)
X	X	X	X	X	1	DATA BUS — 3-STATE (NO OPERATION)

Notes: 1. Selection of IRR, ISR or Interrupting Level is based on the content of OCW3 written before the READ operation.
2. On-chip sequencer logic queues these commands into proper sequence.

8259A Basic Operation

PRELIMINARY
Notice: This is not a final specification. Some parameters are subject to change.

INITIALIZATION COMMAND WORDS 1 AND 2 (ICW1, ICW2)

A_5-A_{15}: *Page starting address of service routines.* In an MCS 80/85 system, the 8 request levels will generate CALLs to 8 locations equally spaced in memory. These can be programmed to be spaced at intervals of 4 or 8 memory locations, thus the 8 routines will occupy a page of 32 or 64 bytes, respectively.

The address format is 2 bytes long (A_0-A_{15}). When the routine interval is 4, A_0-A_4 are automatically inserted by the 8259A, while A_5-A_{15} are programmed externally. When the routine interval is 8, A_0-A_5 are automatically inserted by the 8259A, while A_6-A_{15} are programmed externally.

The 8-byte interval will maintain compatibility with current software, while the 4-byte interval is best for a compact jump table.

In an MCS-86 system T7-T3 are inserted in the five most significant bits of the vectoring byte and the 8259A sets the three least significant bits according to the interrupt level. A_{10}-A_5 are ignored and ADI (Address Interval) has no effect.

LTIM: If LTIM = 1, then the 8259A will operate in the level interrupt mode. Edge detect logic on the interrupt inputs will be disabled.

ADI: CALL address interval. ADI = 1 then interval = 4; ADI = 0 then interval = 8.

SNGL: Single. Means that this is the only 8259A in the system. If SNGL = 1 no ICW3 will be issued.

IC4: If this bit is set — ICW4 has to be read. If ICW4 is not needed, set IC4 = 0.

INITIALIZATION COMMAND WORD 3 (ICW3)

This word is read only when there is more than one 8259A in the system and cascading is used, in which case SNGL = 0. It will load the 8-bit slave register. The functions of this register are:

a. In the master mode (either when $\overline{SP}$ = 1, or in buffered mode when M/S = 1 in ICW4) a "1" is set for each slave in the system. The master then will release byte 1 of the call sequence (for MCS-80/85 system) and will enable the corresponding slave to release bytes 2 and 3 (for 8086/8088 only byte 2) through the cascade lines.

b. In the slave mode (either when $\overline{SP}$ = 0, or if BUF = 1 and M/S = 0 in ICW4) bits 2-0 identify the slave. The slave compares its cascade input with these bits and if they are equal, bytes 2 and 3 of the call sequence (or just byte 2 for 8086/8088) are released by it on the Data Bus.

INITIALIZATION COMMAND WORD 4 (ICW4)

SFNM: If SFNM = 1 the special fully nested mode is programmed.

BUF: If BUF = 1 the buffered mode is programmed. In buffered mode $\overline{SP}/\overline{EN}$ becomes an enable output and the master/slave determination is by M/S.

M/S: If buffered mode is selected: M/S = 1 means the 8259A is programmed to be a master, M/S = 0 means the 8259A is programmed to be a slave. If BUF = 0, M/S has no function.

AEOI: If AEOI = 1 the automatic end of interrupt mode is programmed.

μPM: Microprocessor mode: μPM = 0 sets the 8259A for MCS-80/85 system operation, μPM = 1 sets the 8259A for MCS-86 system operation.

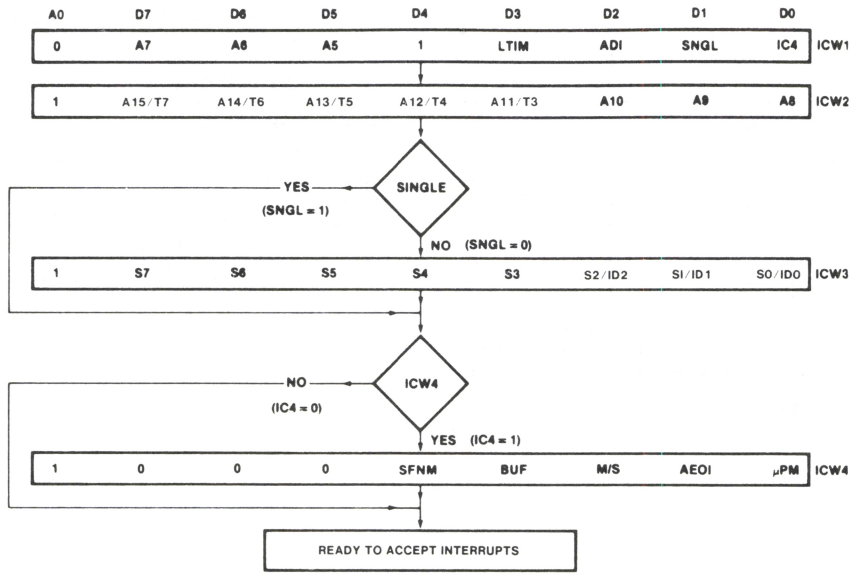
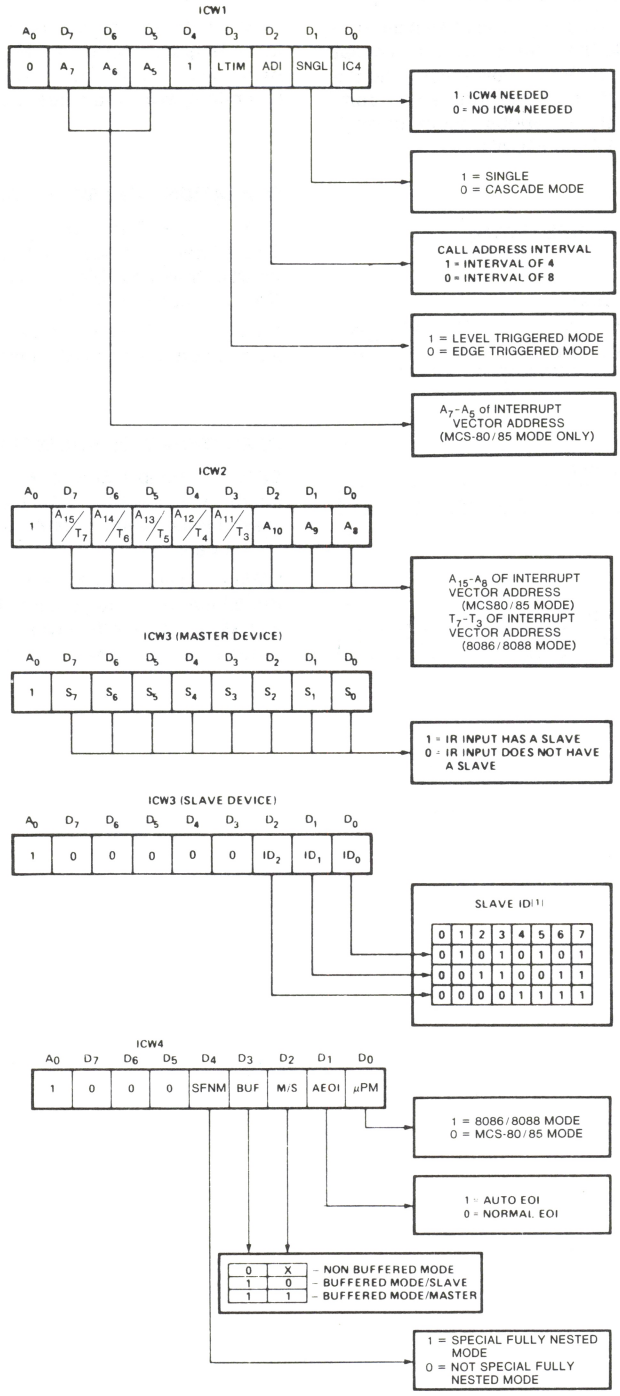


Figure 1. Initialization Sequence

PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.



NOTE 1: SLAVE ID IS EQUAL TO THE CORRESPONDING MASTER IR INPUT.

Initialization Command Word Format

PRELIMINARY
Notice: This is a product in development. Some parameters are subject to change.

OPERATION COMMAND WORDS (OCWs)

After the Initialization Command Words (ICWs) are programmed into the 8259A, the chip is ready to accept interrupt requests at its input lines. However, during the 8259A operation, a selection of algorithms can command the 8259A to operate in various modes through the Operation Command Words (OCWs).

OPERATION CONTROL WORDS (OCWs)

OCW1

A0	D7	D6	D5	D4	D3	D2	D1	D0
1	M7	M6	M5	M4	M3	M2	M1	M0

OCW2

0	R	SL	EOI	0	0	L2	L1	L0

OCW3

0	0	ESMM	SMM	0	1	P	RR	RIS

OPERATION CONTROL WORD 1 (OCW1)

OCW1 sets and clears the mask bits in the interrupt Mask Register (IMR). $M_7 - M_0$ represent the eight mask bits. M = 1 indicates the channel is masked (inhibited), M = 0 indicates the channel is enabled.

OPERATION CONTROL WORD 2 (OCW2)

R, SL, EOI — These three bits control the Rotate and End if Interrupt modes and combinations of the two. A chart of these combinations can be found on the Operation Command Word Format.

L_2, L_1, L_0 — These bits determine the interrupt level acted upon when the SEOI bit is active.

OPERATION CONTROL WORD 3 (OCW3)

ESMM — Enable Special Mask Mode. When this bit is set to 1 it enables the SMM bit to set or reset the Special Mask Mode. When ESMM = 0 the SMM bit becomes a "don't care".

SMM — Special Mask Mode. If ESMM = 1 and SMM = 1 the 8259A will enter Special Mask Mode. If ESMM = 1 and SMM = 0 the 8259A will revert to normal mask mode. When ESMM = 0, SMM has no effect.

PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

OCW1

A_0	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
1	M7	M6	M5	M4	M3	M2	M1	M0

INTERRUPT MASK
1 = MASK SET
0 = MASK RESET

OCW2

A_0	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
0	R	SL	EOI	0	0	L_2	L_1	L_0

IR LEVEL TO BE ACTED UPON

0	1	2	3	4	5	6	7
0	1	0	1	0	1	0	1
0	0	1	1	0	0	1	1
0	0	0	0	1	1	1	1

0	0	1	Non-specific EOI Command	END OF INTERRUPT
0	1	1	*Specific EOI Command	
1	0	1	Rotate On Non-Specific EOI Command	AUTOMATIC ROTATION
1	0	0	Rotate In Automatic EOI Mode (SET)	
0	0	0	Rotate In Automatic EOI Mode (CLEAR)	
1	1	1	*Rotate On Specific EOI Command	SPECIFIC ROTATION
1	1	0	*Set Priority Command	
0	1	0	No operation	

*L0-L2 are used

OCW3

A_0	D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
0	—	ESMM	SMM	0	1	P	RR	RIS

DON'T CARE

READ REGISTER COMMAND

0	1	0	1
0	0	1	1
NO ACTION		READ IR REG ON NEXT $\overline{RD}$ PULSE	READ IS REG ON NEXT $\overline{RD}$ PULSE

1 = POLL COMMAND
0 = NO POLL COMMAND

SPECIAL MASK MODE

0	1	0	1
0	0	1	1
NO ACTION		RESET SPECIAL MASK	SET SPECIAL MASK

Operation Command Word Format

PRELIMINARY
Notice: This is a preliminary data sheet. Some parameters and specifications are subject to change.

INTERRUPT MASKS

Each Interrupt Request input can be masked individually by the Interrupt Mask Register (IMR) programmed through OCW1. Each bit in the IMR masks one interrupt channel if it is set (1). Bit 0 masks IR0, Bit 1 masks IR1 and so forth. Masking an IR channel does not affect the other channels operation.

SPECIAL MASK MODE

Some applications may require an interrupt service routine to dynamically alter the system priority structure during its execution under software control. For example, the routine may wish to inhibit lower priority requests for a portion of its execution but enable some of them for another portion.

The difficulty here is that if an Interrupt Request is acknowledged and an End of Interrupt command did not reset its IS bit (i.e., while executing a service routine), the 8259A would have inhibited all lower priority requests with no easy way for the routine to enable them

That is where the Special Mask Mode comes in. In the special Mask Mode, when a mask bit is set in OCW1, it inhibits further interrupts at that level *and enables* interrupts from *all other* levels (lower as well as higher) that are not masked.

Thus, any interrupts may be selectively enabled by loading the mask register.

The special Mask Mode is set by OCW3 where: SMM = 1, SMM = 1, and cleared where SMM = 1, SMM = 0.

BUFFERED MODE

When the 8259A is used in a large system where bus driving buffers are required on the data bus and the cascading mode is used, there exists the problem of enabling buffers.

The buffered mode will structure the 8259A to send an enable signal on $\overline{SP}/\overline{EN}$ to enable the buffers. In this mode, whenever the 8259A's data bus outputs are enabled, the $\overline{SP}/\overline{EN}$ output becomes active.

This modification forces the use of software programming to determine whether the 8259A is a master or a slave. Bit 3 in ICW4 programs the buffered mode, and bit 2 in ICW4 determines whether it is a master or a slave.

FULLY NESTED MODE

This mode is entered after initialization unless another mode is programmed. The interrupt requests are ordered in priority form 0 through 7 (0 highest). When an interrupt is acknowledged the highest priority request is determined and its vector placed on the bus. Additionally, a bit of the Interrupt Service register (ISO-7) is set. This bit remains set until the microprocessor issues an End of Interrupt (EOI) command immediately before returning from the service routine, or if AEOI (Automatic End of Interrupt) bit is set, until the trailing edge of the last INTA. While the IS bit is set, all further interrupts of the same or lower priority are inhibited, while higher levels will generate an interrupt (which will be acknowledged only if the microprocessor internal Interrupt enable flip-flop has been re-enabled through software).

After the initialization sequence, IR0 has the highest priority and IR7 the lowest. Priorities can be changed, as will be explained, by priority rotation.

THE SPECIAL FULLY NESTED MODE

This mode will be used in the case of a big system where cascading is used, and the priority has to be conserved within each slave. In this case the special fully nested mode will be programmed to the master (using) ICW4). This mode is similar to the normal fully nested mode with the following exceptions:

a. When an interrupt request from a certain slave is in service this slave is not locked out from the master's priority logic and further interrupt requests from higher priority IR's within the slave will be recognized by the master and will initiate interrupts to the processor. (In the normal nested mode a slave is masked out when its request is in service and no higher requests from the same slave can be serviced.)

b. When exiting the Interrupt Service routine the software has to check whether the interrupt serviced was the only one from that slave. This is done by sending a non-specific End of Interrupt (EOI) command to the slave and then reading its In-Service register and checking for zero. If it is empty, a non-specific EOI can be sent to the master too. If not, no EOI should be sent.

PRELIMINARY
Notice: This is not a final specification. Some parameters are subject to change.

POLL

In this mode the microprocessor internal Interrupt Enable flip-flop is reset, disabling its interrupt input. Service to devices is achieved by programmer initiative using a Poll command.

The Poll command is issued by setting P = "1" in OCW3. The 8259A treats the next $\overline{RD}$ pulse to the 8259A (i.e., $\overline{RD}$ = 0, $\overline{CS}$ = 0) as an interrupt acknowledge, sets the appropriate IS bit if there is a request, and reads the priority level. Interrupt is frozen from $\overline{WR}$ to $\overline{RD}$.

The word enabled onto the data bus during $\overline{RD}$ is:

D7	D6	D5	D4	D3	D2	D1	D0
I	–	–	–	–	W2	W1	W0

W0-W2: Binary code of the highest priority level requesting service.

I: Equal to a "1" if there is an interrupt.

This mode is useful if there is a routine command common to several levels so that the $\overline{INTA}$ sequence is not needed (saves ROM space). Another application is to use the poll command to expand the number of priority levels to more than 64.

END OF INTERRUPT (EOI)

The In Service (IS) bit can be reset either automatically following the trailing edge of the last in sequence $\overline{INTA}$ pulse (when AEOI bit in ICW1 is set) or by a command word that must be issued to the 8259A before returning from a service routine (EOI command). An EOI command must be issued twice, once for themaster and once for the corresponding slave if slaves are in use.

There are two forms of EOI command: Specific and Non-Specific. When the 8259A is operated in modes which preserve the fully nested structure, it can determine which IS bit to reset on EOI. When a Non-Specific EOI command is issued the 8259A will automatically reset the highest IS bit of those that are set, since in the nested mode the highest IS level was necessarily the last level acknowledged and serviced.

However, when a mode is used which may disturb the fully nested structure, the 8259A may no longer be able to determine the last level acknowledged. In this case a Specific End of Interrupt (SEOI) must be issued which includes as part of the command the IS level to be reset. EOI is issued whenever EOI = 1, in OCW2, where L0-L2 is the binary level of the IS bit to be reset. Note that although the Rotate command can be issued together with an EOI where EOI = 1, it is not necessarily tied to it.

It should be noted that an IS bit that is masked by an IMR bit will not be cleared by a non-specific EOI if the 8259A is in the Special Mask Mode.

AUTOMATIC END OF INTERRUPT (AEOI) MODE

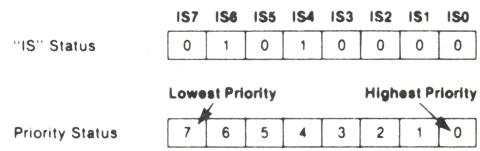
If AEOI = 1 in ICW4, then the 8259A will operate in AEOI mode continuously until reprogrammed by ICW4. In this mode the 8259A will automatically perform a non-specific EOI operation at the trailing edge of the last interrupt acknowledge pulse (third pulse in MCS-80/85, second in MCS-86). Note that from a system standpoint, this mode should be used only when a nested multilevel interrupt structure is not required within a single 8259A.

To achieve automatic rotation within AEOI, there is a special rotate flip-flop. It is set by OCW2 with R = 1, SL = 0. EOI = 0, and cleared with R = 0, SEOI = 0, EOI = 0.

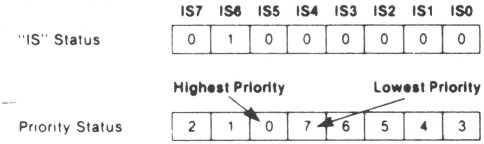
AUTOMATIC ROTATION (Equal Priority Devices)

In some applications there are a number of interrupting devices of equal priority. In this mode a device, after being serviced, receives the lowest priority, so a device requesting an interrupt will have to wait, in the worst case until each of 7 other devices are serviced at most *once*. For example, if the priority and "in service" status is:

Before Rotate (IR4 the highest priority requiring service)



After Rotate (IR4 was serviced, all other priorities rotated correspondingly)



There are two ways to accomplish Automatic Rotation using OCW2, the Rotate on Non-Specific EOI Command (R = 1, SL = 0, EOI = 1) and the Rotate in Automatic EOI Mode which is set by (R = 1, SL = 0, EOI = 0) and cleared by (R = 0 SL = 0, EOI = 0).

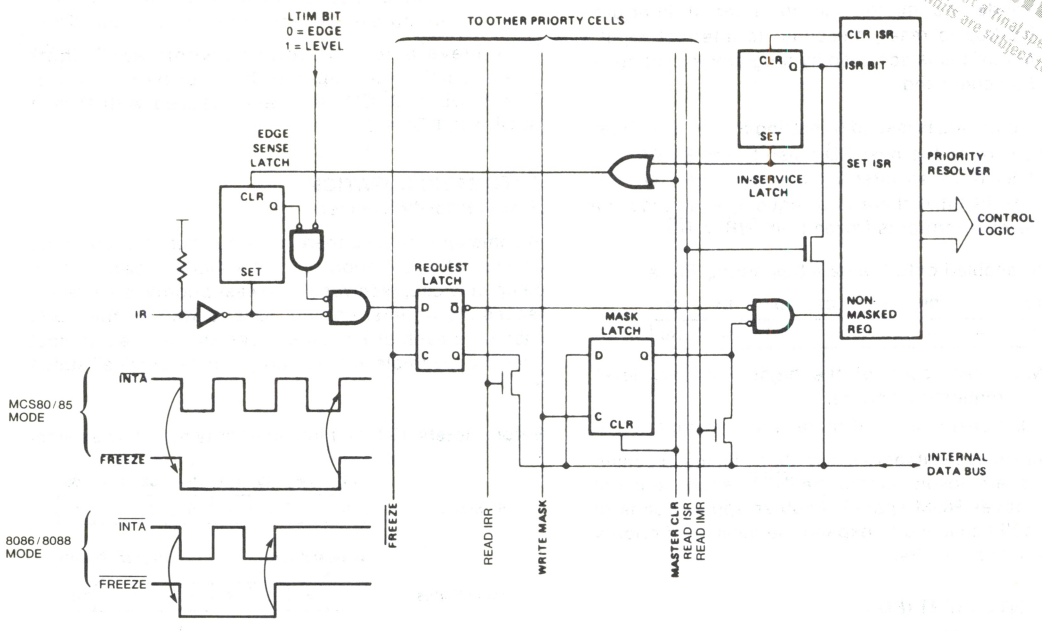
SPECIFIC ROTATION (Specific Priority)

The programmer can change priorities by programming the bottom priority and thus fixing all other priorities; i.e., if IR5 is programmed as the bottom priority device, then IR6 will have the highest one.

The Set Priority command is issued in OCW2 where: R = 1, SEOI = 1; L0-L2 is the binary priority level code of the bottom priority device.

Observe that in this mode internal status is updated by software control during OCW2. However, it is independent of the End of Interrupt (EOI) command (also executed by OCW2). Priority changes can be executed during an EOI command by using the Rotate on Specific EOI Command in OCW2 (R = 1, SL = 1, EOI = 1 and L0-L2 = IR level to receive bottom priority).

PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.



NOTES

1. MASTER CLEAR ACTIVE ONLY DURING ICW1
2. FREEZE/ IS ACTIVE DURING $\overline{INTA}$/ AND POLL SEQUENCES ONLY
3. TRUTH TABLE FOR D-LATCH

C	D	Q	OPERATION
1	Di	Di	FOLLOW
0	X	Qn-1	HOLD

Priority Cell — Simplified Logic Diagram

LEVEL TRIGGERED MODE

This mode is programmed using bit 3 in ICW1.

If LTIM = '1,' an interrupt request will be recognized by a 'high' level on IR Input, and there is no need for an edge detection. The interrupt request must be removed before the EOI command is issued or the CPU interrupt is enabled to prevent a second interrupt from occurring.

The above figure shows a conceptual circuit to give the reader an understanding of the level sensitive and edge sensitive input circuitry of the 8259A. Be sure to note that the request latch is a transparent D type latch.

READING THE 8259A STATUS

The input status of several internal registers can be read to update the user information on the system. The following registers can be read via OCW3 (IRR and ISR or OCW1 (IMR).

Interrupt Request Register (IRR): 8-bit register which contains the levels requesting an interrupt to be acknowledged. The highest request level is reset from the IRR when an interrupt is acknowledged. (Not affected by IMR).

In-Service Register (ISR): 8-bit register which contains the priority levels that are being serviced. The ISR is updated when an End of Interrupt command is issued.

Interrupt Mask Register: 8-bit register which contains the interrupt request lines which are masked.

The IRR can be read when, prior to the $\overline{RD}$ pulse, a Read Register Command is issued with OCW3 (RR = 1, RIS = 0).

The ISR can be read when, prior to the $\overline{RD}$ pulse, a Read Register Command is issued with OCW3 (RR = 1, RIS = 1).

There is no need to write an OCW3 before every status read operation, as long as the status read corresponds with the previous one; i.e., the 8259A "remembers" whether the IRR or ISR has been previously selected by the OCW3. This is not true when poll is used.

After initialization the 8259A is set to IRR.

For reading the IMR, no OCW3 is needed. The output data bus will contain the IMR whenever $\overline{RD}$ is active and A0 = 1 (OCW1).

Polling overrides status read when P = 1, RR = 1 in OCW3.

PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

SUMMARY OF 8259A INSTRUCTION SET

Inst. #	Mnemonic		A0	D7	D6	D5	D4	D3	D2	D1	D0	Operation Description
1	ICW1	A	0	A7	A6	A5	1	0	1	1	0	Format = 4, single, edge triggered
2	ICW1	B	0	A7	A6	A5	1	1	1	1	0	Format = 4, single, level triggered
3	ICW1	C	0	A7	A6	A5	1	0	1	0	0	Byte 1 Initialization — Format = 4, not single, edge triggered
4	ICW1	D	0	A7	A6	A5	1	1	1	0	0	Format = 4, not single, level triggered
5	ICW1	E	0	A7	A6	0	1	0	0	1	0	No ICW4 Required — Format = 8, single, edge triggered
6	ICW1	F	0	A7	A6	0	1	1	0	1	0	Format = 8, single, level triggered
7	ICW1	G	0	A7	A6	0	1	0	0	0	0	Format = 8, not single, edge triggered
8	ICW1	H	0	A7	A6	0	1	1	0	0	0	Format = 8, not single, level triggered
9	ICW1	I	0	A7	A6	A5	1	0	1	1	1	Format = 4, single, edge triggered
10	ICW1	J	0	A7	A6	A5	1	1	1	1	1	Format = 4, single, level triggered
11	ICW1	K	0	A7	A6	A5	1	0	1	0	1	Byte 1 Initialization — Format = 4, not single, edge triggered
12	ICW1	L	0	A7	A6	A5	1	1	1	0	1	Format = 4, not single, level triggered
13	ICW1	M	0	A7	A6	0	1	0	0	1	1	ICW4 Required — Format = 8, single, edge triggered
14	ICW1	N	0	A7	A6	0	1	1	0	1	1	Format = 8, single, level triggered
15	ICW1	O	0	A7	A6	0	1	0	0	0	1	Format = 8, not single, edge triggered
16	ICW1	P	0	A7	A6	0	1	1	0	0	1	Format = 8, not single, level triggered
17	ICW2		1	A15	A14	A13	A12	A11	A10	A9	A8	Byte 2 initialization
18	ICW3	M	1	S7	S6	S5	S4	S3	S2	S1	S0	Byte 3 initialization — master
19	ICW3	S	1	0	0	0	0	0	S2	S1	S0	Byte 3 initialization — slave
20	ICW4	A	1	0	0	0	0	0	0	0	0	No action, redundant
21	ICW4	B	1	0	0	0	0	0	0	0	1	Non-buffered mode, no AEOI, 8086/8088
22	ICW4	C	1	0	0	0	0	0	0	1	0	Non-buffered mode, AEOI, MCS-80/85
23	ICW4	D	1	0	0	0	0	0	0	1	1	Non-buffered mode, AEOI, 8086/8088
24	ICW4	E	1	0	0	0	0	0	1	0	0	No action, redundant
25	ICW4	F	1	0	0	0	0	0	1	0	1	Non-buffered mode, no AEOI, 8086/8088
26	ICW4	G	1	0	0	0	0	0	1	1	0	Non-buffered mode, AEOI, MCS-80/85
27	ICW4	H	1	0	0	0	0	0	1	1	1	Non-buffered mode, AEOI, 8086/8088
28	ICW4	I	1	0	0	0	0	1	0	0	0	Buffered mode, slave, no AEOI, MCS-80/85
29	ICW4	J	1	0	0	0	0	1	0	0	1	Buffered mode, slave, no AEOI, 8086/8088
30	ICW4	K	1	0	0	0	0	1	0	1	0	Buffered mode, slave, AEOI, MCS-80/85
31	ICW4	L	1	0	0	0	0	1	0	1	1	Buffered mode, slave, AEOI, 8086/8088
32	ICW4	M	1	0	0	0	0	1	1	0	0	Buffered mode, master, no AEOI, MCS-80/85
33	ICW4	N	1	0	0	0	0	1	1	0	1	Buffered mode, master, no AEOI, 8086/8088
34	ICW4	O	1	0	0	0	0	1	1	1	0	Buffered mode, master, AEOI, MCS-80/85
35	ICW4	P	1	0	0	0	0	1	1	1	1	Buffered mode, master AEOI, 8086, 8088
36	ICW4	NA	1	0	0	0	1	0	0	0	0	Fully nested mode, MCS-80, non buffered, no AEOI
37	ICW4	NB	1	0	0	0	1	0	0	0	1	ICW4 NB through ICW4 ND are identical to ICW4 B through ICW4 D with the addition of Fully Nested Mode
38	ICW4	NC	1	0	0	0	1	0	0	1	0	
39	ICW4	ND	1	0	0	0	1	0	0	1	1	
40	ICW4	NE	1	0	0	0	1	0	1	0	0	Fully Nested Mode, MCS-80/85, non-buffered, no AEOI
41	ICW4	NF	1	0	0	0	1	0	1	0	1	ICW4 NF through ICW4 NP are identical to ICW4 F through ICW4 P with the addition of Fully Nested Mode
42	ICW4	NG	1	0	0	0	1	0	1	1	0	
43	ICW4	NH	1	0	0	0	1	0	1	1	1	
44	ICW4	NI	1	0	0	0	1	1	0	0	0	
45	ICW4	NJ	1	0	0	0	1	1	0	0	1	
46	ICW4	NK	1	0	0	0	1	1	0	1	0	
47	ICW4	NL	1	0	0	0	1	1	0	1	1	
48	ICW4	NM	1	0	0	0	1	1	1	0	0	
49	ICW4	NN	1	0	0	0	1	1	1	0	1	
50	ICW4	NO	1	0	0	0	1	1	1	1	0	
51	ICW4	NP	1	0	0	0	1	1	1	1	1	
52	OCW1		1	M7	M6	M5	M4	M3	M2	M1	M0	Load mask register, read mask register
53	OCW2	E	0	0	0	1	0	0	0	0	0	Non-specific EOI
54	OCW2	SE	0	0	1	1	0	0	L2	L1	L0	Specific EOI, L0-L2 code of IS FF to be reset
55	OCW2	RE	0	1	0	1	0	0	0	0	0	Rotate on Non-Specific EOI
56	OCW2	RSE	0	1	1	1	0	0	L2	L1	L0	Rotate on Specific EOI L0-L2 code of line
57	OCW2	R	0	1	0	0	0	0	0	0	0	Rotate in Auto EOI (set)
58	OCW2	CR	0	0	0	0	0	0	0	0	0	Rotate in Auto EOI (clear)
59	OCW2	RS	0	1	1	0	0	0	L2	L1	L0	Set Priority Command
60	OCW3	P	0	0	0	0	0	1	1	0	0	Poll mode
61	OCW3	RIS	0	0	0	0	0	1	0	1	1	Read IS register

PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

SUMMARY OF 8259A INSTRUCTION SET (Cont.)

Inst. #	Mnemonic	A0	D7	D6	D5	D4	D3	D2	D1	D0	Operation Description
46	OCW3 RR	0	0	0	0	0	1	0	1	0	Read request register
47	OCW3 SM	0	0	1	1	0	1	0	0	0	Set special mask mode
48	OCW3 RSM	0	0	1	0	0	1	0	0	0	Reset special mask mode

Note: 1. In the master mode $\overline{SP}$ pin = 1, in slave mode $\overline{SP}$ = 0

Cascading

The 8259A can be easily interconnected in a system of one master with up to eight slaves to handle up to 64 priority levels.

A typical MCS-80/85 system is shown in Figure 2. The master controls, through the 3 line cascade bus, which one of the slaves will release the corresponding address.

As shown in Figure 2, the slave interrupt outputs are connected to the master interrupt request inputs. When a slave request line is activated and afterwards acknowledged, the master will enable the corresponding slave to release the device routine address during bytes 2 and 3 of $\overline{INTA}$. (Byte 2 only for 8086/8088).

The cascade bus lines are normally low and will contain the slave address code from the trailing edge of the first $\overline{INTA}$ pulse to the trailing edge of the third pulse. It is obvious that each 8259A in the system must follow a separate initialization sequence and can be programmed to work in a different mode. An EOI command must be issued twice: once for the master and once for the corresponding slave. An address decoder is required to activate the Chip Select ($\overline{CS}$) input of each 8259A.

The cascade lines of the Master 8259A are activated for any interrupt input, even if no slave is connected to that input.

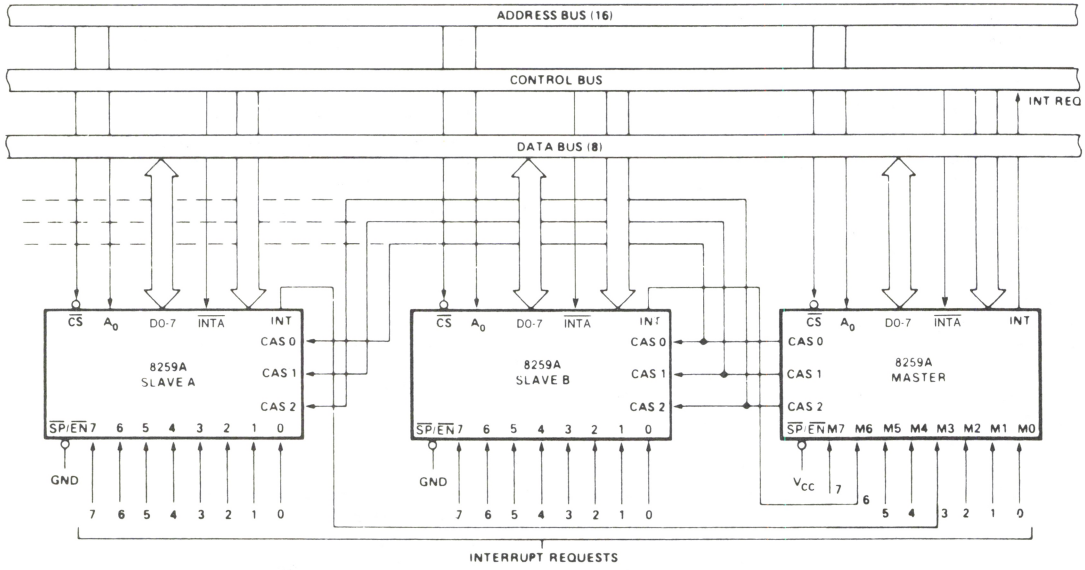


Figure 2. Cascading the 8259A

PRELIMINARY
Notice: This is a product in development. Some parametric limits are subject to change.

PIN FUNCTIONS

NAME	I/O	PIN#	FUNCTION
V_{CC}	I	28	+5v supply
GND	I	14	Ground
$\overline{CS}$	I	1	Chip Select A low on this pin enables RD and WR communication between the CPU and the 8259A. INTA functions are independent of CS.
$\overline{WR}$	I	2	Write: A low on this pin when CS is low, enables the 8259A to accept command words from the CPU.
$\overline{RD}$	I	3	Read: A low on this pin when CS is low enables the 8259A to release status onto the data bus for the CPU.
D_7-D_0	I/O	4-11	Bidirectional Data Bus: Control, status and interrupt-vector information is transferred via this bus.
CAS_0-CAS_2	I/O	12,13,15	Cascade Lines: The CAS lines form a private 8259A bus to control a multiple 8259A structure. These pins are outputs for a master 8259A and inputs for a slave 8259A.
$\overline{SP}/\overline{EN}$	I/O	16	Slave Program/Enable Buffer: This is a dual function pin. When in the Buffered Mode it can be used as an output to control buffer transceivers (EN). When not in the buffered mode it is used as an input to designate a master (SP = 1) or slave (SP = 0).
INT	O	17	Interrupt: This pin goes high whenever a valid interrupt request is asserted. It is used to interrupt the CPU, thus it is connected to the CPU's interrupt pin.
IR_0-IR_7	I	18-25	Interrupt Requests: Asynchronous inputs. An interrupt request can be generated by raising an IR input (low to high) and holding it high until it is acknowledged (Edge Triggered Mode), or just by a high level on an IR input (Level Triggered Mode).
$\overline{INTA}$	I	26	Interrupt Acknowledge: This pin is used to enable 8259A interrupt-vector data onto the data bus. This is done by a sequence of interrupt acknowledge pulses issued by the CPU.
A_0	I	27	A0 Address Line: This pin acts in conjunction with the $\overline{CS}$, $\overline{WR}$, and $\overline{RD}$ pins. It is used by the 8259A to decipher between various Command Words the CPU writes and status the CPU wishes to read. It is typically connected to the CPU A0 address line (A1 for 8086/8088).

ABSOLUTE MAXIMUM RATINGS*

Ambient Temperature Under Bias ..... −40°C to 85°C
Storage Temperature ..... −65°C to +150°C
Voltage On Any Pin
With Respect to Ground ..... −0.5V to +7V
Power Dissipation ..... 1 Watt

COMMENT
Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

D.C. CHARACTERISTICS

$T_A = 0°C$ to $70°C$, $V_{CC} = 5V \pm 10\%$ (8259-A), $V_{CC} = 5V \pm 10\%$ (8259A)

Symbol	Parameter	Min.	Max.	Units	Test Conditions
V_{IL}	Input Low Voltage	-.5	V		
V_{IH}	Input High Voltage	2.0	V_{CC} + .5V	V	
V_{OL}	Output Low Voltage		.45	V	$I_{OL} = 2.2$ mA
V_{OH}	Output High Voltage	2.4		V	$I_{OH} = -400\ \mu A$
$V_{OH(INT)}$	Interrupt Output High Voltage	3.5 2.4		C V	$I_{OH} = -100\ \mu A$ $I_{OH} = -400\ \mu A$
I_{LI}	Input Load Current		10	μA	$V_{IN} = V_{CC}$ to 0V
I_{LOL}	Output Leakage Current		-10	μA	$V_{OUT} = 0.45V$
I_{CC}	V_{CC} Supply Current		85	mA	
I_{LIR}	IR Input Load Current		-300 10	μA μA	$V_{IN} = 0$ $V_{IN} = V_{CC}$

PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

8259A A.C. CHARACTERISTICS

$T_A = 0°C$ to $70°C$ $V_{CC} = 5V \pm 5\%$ (8259A-8) $V_{CC} = 5V \pm 10\%$ (8259A)

TIMING REQUIREMENTS

Symbol	Parameter	8259A-8		8259A		8259A-2		Units	Test Conditions
		Min.	Max.	Min.	Max.	Min.	Max.		
TAHRL	A0/$\overline{CS}$ Setup to $\overline{RD}$/$\overline{INTA}\downarrow$	50		0		0		ns	
TRHAX	A0/$\overline{CS}$ Hold after $\overline{RD}$/$\overline{INTA}\uparrow$	5		0		0		ns	
TRLRH	$\overline{RD}$ Pulse Width	420		235		160		ns	
TAHWL	A0/$\overline{CS}$ Setup to $\overline{WR}\downarrow$	50		0		0		ns	
TWHAX	A0/$\overline{CS}$ Hold after $\overline{WR}\uparrow$	20		0		0		ns	
TWLWH	$\overline{WR}$ Pulse Width	400		290		190		ns	
TDVWH	Data Setup to $\overline{WR}\uparrow$	300		240		160		ns	
TWHDX	Data Hold after $\overline{WR}\uparrow$	40		0		0		ns	
TJLJH	Interrupt Request Width (Low)	100		100		100		ns	See Note 1
TCVIAL	Cascade Setup to Second or Third $\overline{INTA}\downarrow$ (Slave Only)	55		55		40		ns	
TRHRL	End of $\overline{RD}$ to Next Command	160		160		160		ns	
TWHRL	End of $\overline{WR}$ to Next Command	190		190		190		ns	

Note: This is the low time required to clear the input latch in the edge triggered mode.

TIMING RESPONSES

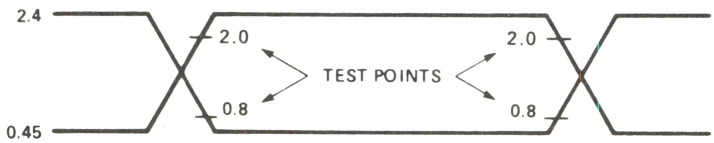
Symbol	Parameter	8259A-8		8259A		8259A-2		Units	Test Conditions
		Min.	Max.	Min.	Max.	Min.	Max.		
TRLDV	Data Valid from $\overline{RD}$/$\overline{INTA}\downarrow$		300		200		120	ns	C of Data Bus = 100 pF
TRHDZ	Data Float after $\overline{RD}$/$\overline{INTA}\uparrow$	10	200		100		85	ns	C of Data Bus Max text C = 100 pF Min. test C = 15 pF
TJHIH	Interrupt Output Delay		400		350		300	ns	
TIAHCV	Cascade Valid from First $\overline{INTA}\downarrow$ (Master Only)		565		565		360	ns	C_{INT} = 100 pF
TRLEL	Enable Active from $\overline{RD}\downarrow$ or $\overline{INTA}\downarrow$		160		125		100	ns	$C_{CASCADE}$ = 100 pF
TRHEH	Enable Inactive from $\overline{RD}\uparrow$ or $\overline{INTA}\uparrow$		325		150		d150	ns	
TAHDV	Data Valid from Stable Address		350		200		200	ns	
TCVDV	Cascade Valid to Valid Data		300		300		200	ns	

CAPACITANCE

$T_A = 25°C$; $V_{CC} = GND = 0V$

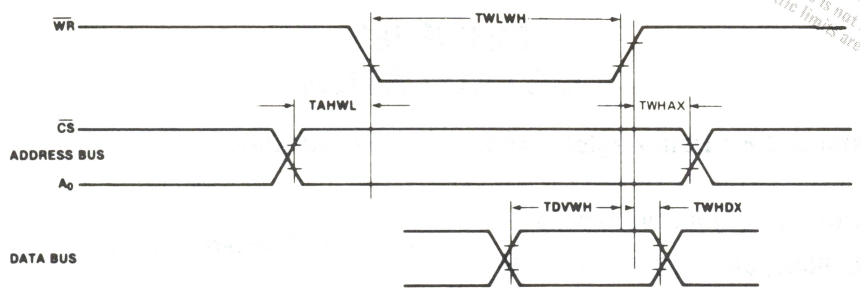
Symbol	Parameter	Min.	Typ.	Max.	Unit	Test Conditions
C_{IN}	Input Capacitance			10	pF	fc = 1 MHz
$C_{I/O}$	I/O Capacitance			20	pF	Unmeasured pins returned to V_{SS}

Input and Output Waveforms for A.C. Tests

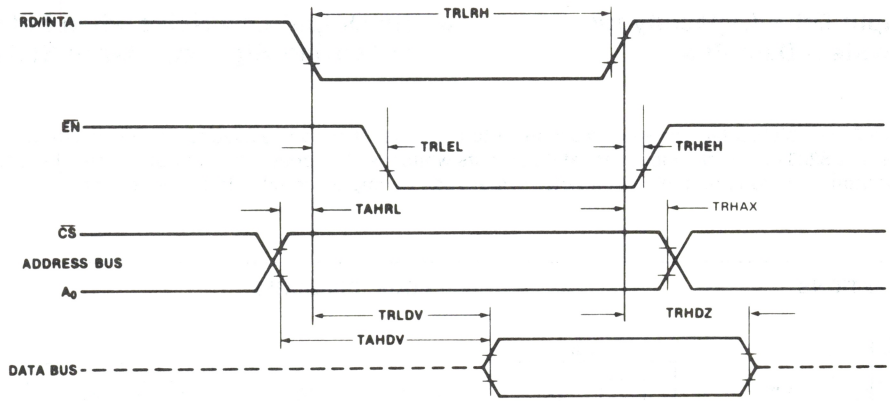


PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

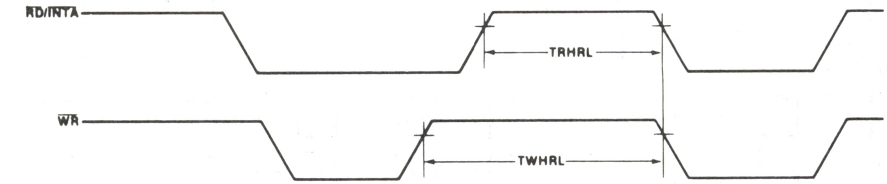
WRITE MODE



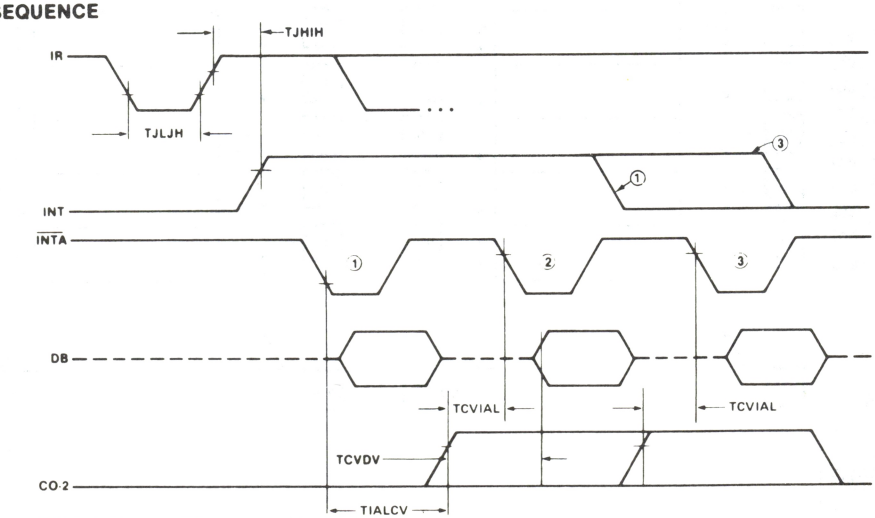
READ/INTA MODE



OTHER TIMING



INTA SEQUENCE



NOTE: Interrupt output must remain HIGH (at least) until leading edge of first INTA
② MCS 80/85 Systems only
① Cycle 1 in MCS 85 Systems: the Data Bus is not active

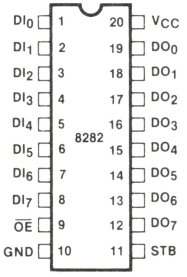
PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

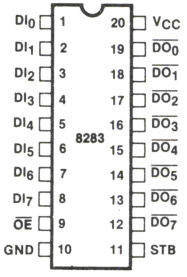
8282/8283
OCTAL LATCH

- **Fully Parallel 8-Bit Data Register and Buffer**
- **Transparent during Active Strobe**
- **Supports 8080, 8085, 8048, and 8086 Systems**
- **High Output Drive Capability for Driving System Data Bus**
- **3-State Outputs**
- **20-Pin Package with 0.3" Center**
- **No Output Low Noise when Entering or Leaving High Impedance State**

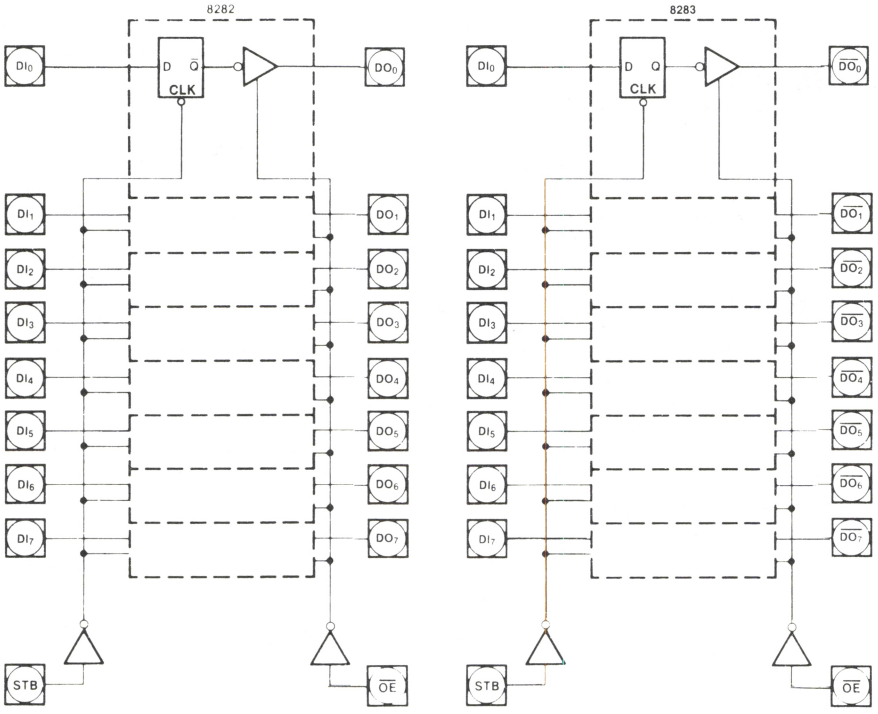
The 8282 and 8283 are 8-bit bipolar latches with 3-state output buffers. They can be used to implement latches, buffers, or multiplexers. The 8283 inverts the input data at its outputs while the 8282 does not. Thus, all of the principal peripheral and input/output functions of a microcomputer system can be implemented with these devices.

PIN CONFIGURATIONS





LOGIC DIAGRAMS



PIN NAMES

DI_0-DI_7	DATA IN
DO_0-DO_7	DATA OUT
$\overline{OE}$	OUTPUT ENABLE
STB	STROBE

PRELIMINARY
Note: This is a product specification. Some parameters may be subject to change.

PIN DEFINITIONS

Pin	Description
STB	STROBE (Input). STB is an input control pulse used to strobe data at the data input pins (A_0-A_7) into the data latches. This signal is active HIGH to admit input data. The data is latched at the HIGH to LOW transition of STB.
$\overline{OE}$	OUTPUT ENABLE (Input). $\overline{OE}$ is an input control signal which when active LOW enables the contents of the data latches onto the data output pin (B_0-B_7). OE being inactive HIGH forces the output buffers to their high impedance state.
DI_0-DI_7	DATA INPUT PINS (Input). Data presented at these pins satisfying setup time requirements when STB is strobed and latched into the data input latches.
DO_0-DO_7 (8282) $\overline{DO_0}$-$\overline{DO_7}$ (8283)	DATA OUTPUT PINS (Output). When $\overline{OE}$ is true, the data in the data latches is presented as inverted (8283) or non-inverted (8282) data onto the data output pins.

OPERATIONAL DESCRIPTION

The 8282 and 8283 octal latches are 8-bit latches with 3-state output buffers. Data having satisfied the setup time requirements is latched into the data latches by strobing the STB line HIGH to LOW. Holding the STB line in its active HIGH state makes the latches appear transparent. Data is presented to the data output pins by activating the $\overline{OE}$ input line. When $\overline{OE}$ is inactive HIGH the output buffers are in their high impedance state. Enabling or disabling the output buffers will not cause negative-going transients to appear on the data output bus.

D.C. AND OPERATING CHARACTERISTICS

ABSOLUTE MAXIMUM RATINGS*

Temperature Under Bias . . . . . 0°C to 70°C
Storage Temperature . . . . . −65°C to +150°C
All Output and Supply Voltages . . . . . −0.5V to +7V
All Input Voltages . . . . . −1.0V to +5.5V
Power Dissipation . . . . . 1 Watt

*COMMENT: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

D.C. CHARACTERISTICS FOR 8282/8283

Conditions: $V_{CC} = 5V \pm 5\%$, $T_A = 0°C$ to $70°C$

Symbol	Parameter	Min	Max	Units	Test Conditions
V_C	Input Clamp Voltage		−1	V	$I_C = -5$ mA
I_{CC}	Power Supply Current		160	mA	
I_F	Forward Input Current		−0.2	mA	$V_F = 0.45V$
I_R	Reverse Input Current		50	μA	$V_R = 5.25V$
V_{OL}	Output Low Voltage		0.50	V	$I_{OL} = 32$ mA
V_{OH}	Output High Voltage	2.4		V	$I_{OH} = -5$ mA
I_{OFF}	Output Off Current		±50	μA	$V_{OFF} = 0.45$ to $5.25V$
V_{IL}	Input Low Voltage		0.8	V	$V_{CC} = 5.0V$ See Note 1
V_{IH}	Input High Voltage	2.0		V	$V_{CC} = 5.0V$ See Note 1
C_{IN}	Input Capacitance		12	pF	$F = 1$ MHz, $V_{BIAS} = 2.5V$, $V_{CC} = 5V$, $T_A = 25°C$

Notes: 1. Output Loading $I_{OL} = 32$ mA, $I_{OH} = -5$ mA, $C_L = 300$ pF

PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

A.C. CHARACTERISTICS FOR 8282/8283

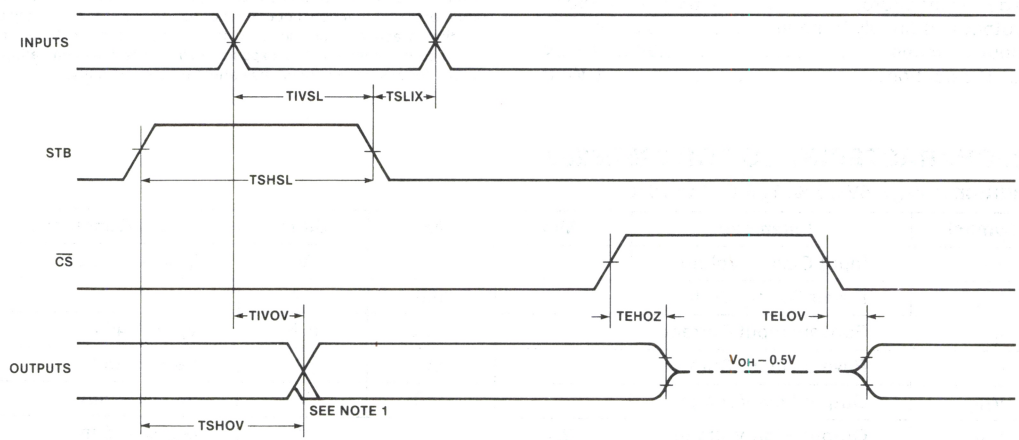
Conditions: $V_{CC} = 5V \pm 5\%$, $T_A = 0°C$ to $70°C$

Loading: Outputs — I_{OL} = 32 mA, I_{OH} = −5 mA, C_L = 300 pF

Symbol	Parameter	Min	Max	Units	Test Conditions
TIVOV	Input to Output Delay				(See Note 1)
	—Inverting		25	ns	
	—Non-Inverting		35	ns	
TSHOV	STB to Output Delay				
	—Inverting		45	ns	
	—Non-Inverting		55	ns	
TEHOZ	Output Disable Time		25	ns	
TELOV	Output Enable Time	10	50	ns	
TIVSL	Input to STB Setup Time	0		ns	
TSLIX	Input to STB Hold Time	25		ns	
TSHSL	STB High Time	15		ns	

NOTE: 1. See waveforms and test load circuit on following page.

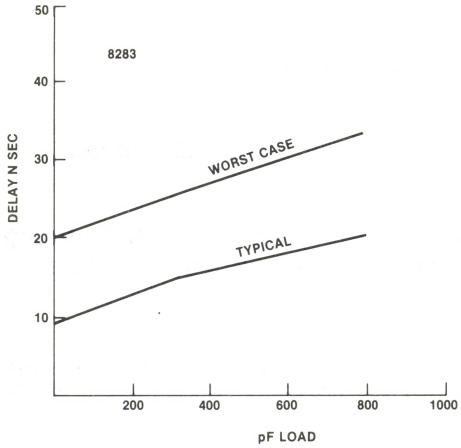
8282/8283 TIMING

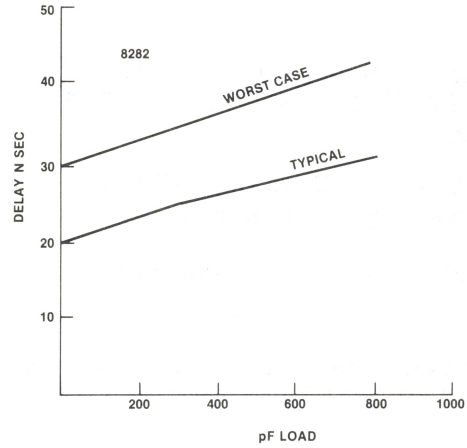


NOTE: 1. 8283 ONLY — OUTPUT MAY BE MOMENTARILY INVALID FOLLOWING THE HIGH GOING STB TRANSITION.
2. ALL TIMING MEASUREMENTS ARE MADE AT 1.5V UNLESS OTHERWISE NOTED

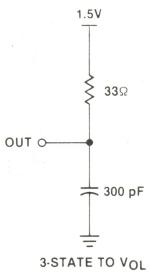
PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

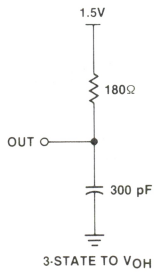
OUTPUT DELAY VS. CAPACITANCE

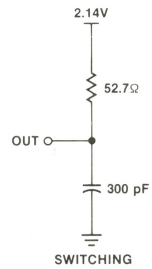




OUTPUT TEST LOAD CIRCUITS





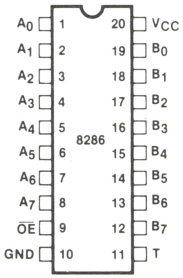


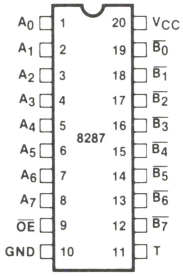
8286/8287
OCTAL BUS TRANSCEIVER

- **Data Bus Buffer Driver for MCS-86™, MCS-80™, MCS-85™, and MCS-48™ Families**
- **High Output Drive Capability for Driving System Data Bus**
- **Fully Parallel 8-Bit Transceivers**
- **3-State Outputs**
- **20-Pin Package with 0.3" Center**
- **No Output Low Noise when Entering or Leaving High Impedance State**

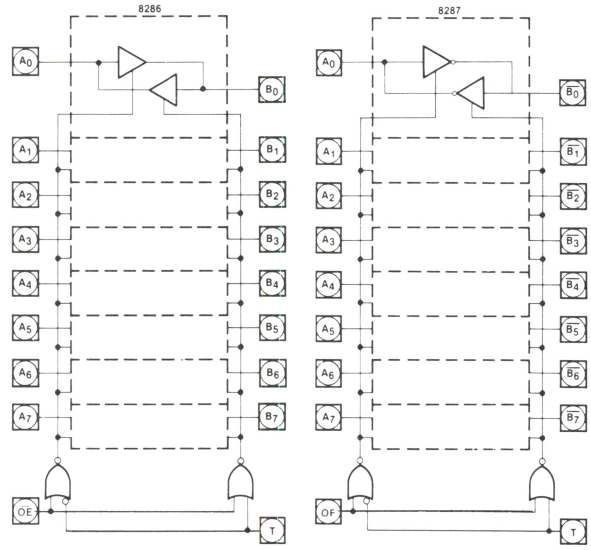
The 8286 and 8287 are 8-bit bipolar transceivers with 3-state outputs. The 8287 inverts the input data at its outputs while the 8286 does not. Thus, a wide variety of applications for buffering in microcomputer systems can be met.

PIN CONFIGURATIONS





LOGIC DIAGRAMS



PIN NAMES

A_0-A_7	LOCAL BUS DATA
B_0-B_7	SYSTEM BUS DATA
$\overline{OE}$	OUTPUT ENABLE
T	TRANSMIT

PIN DEFINITIONS

Pin	Description
T	TRANSMIT (Input). T is an input control signal used to control the direction of the transceivers. When HIGH, it configures the transceiver's B_0-B_7 as outputs with A_0-A_7 as inputs. T LOW configures A_0-A_7 as the outputs with B_0-B_7 serving as the inputs.
$\overline{OE}$	OUTPUT ENABLE (Input). $\overline{OE}$ is an input control signal used to enable the appropriate output driver (as selected by T) onto its respective bus. This signal is active LOW.
A_0-A_7	LOCAL BUS DATA PINS (Input/Output). These pins serve to either present data to or accept data from the processor's local bus depending upon the state of the T pin.
B_0-B_7 (8286) $\overline{B_0}$-$\overline{B_7}$ (8287)	SYSTEM BUS DATA PINS (Input/Output). These pins serve to either present data to or accept data from the system bus depending upon the state of the T pin.

OPERATIONAL DESCRIPTION

The 8286 and 8287 transceivers are 8-bit transceivers with high impedance outputs. With T active HIGH and $\overline{OE}$ active LOW, data at the A_0-A_7 pins is driven onto the B_0-B_7 pins. With T inactive LOW and $\overline{OE}$ active LOW, data at the B_0-B_7 pins is driven onto the A_0-A_7 pins. No output low glitching will occur whenever the transceivers are entering or leaving the high impedance state.

D.C. AND OPERATING CHARACTERISTICS

ABSOLUTE MAXIMUM RATINGS*

Temperature Under Bias . . . . . 0°C to 70°C
Storage Temperature . . . . . −65°C to +150°C
All Output and Supply Voltages . . . . . −0.5V to +7V
All Input Voltages . . . . . −1.0V to +5.5V
Power Dissipation . . . . . 1 Watt

**COMMENT:* Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

D.C. CHARACTERISTICS FOR 8286/8287

Conditions: V_{CC} = 5V ±5%, T_A = 0°C to 70°C

Symbol	Parameter	Min	Max	Units	Test Conditions
V_C	Input Clamp Voltage		-1	V	I_C = -5 mA
I_{CC}	Power Supply Current—8287 —8286		130 160	mA mA	
I_F	Forward Input Current		-0.2	mA	V_F = 0.45V
I_R	Reverse Input Current		50	μA	V_R = 5.25V
V_{OL}	Output Low Voltage —B Outputs —A Outputs		0.5 0.5	V V	I_{OL} = 32 mA I_{OL} = 10 mA
V_{OH}	Output High Voltage —B Outputs —A Outputs	2.4 2.4		V V	I_{OH} = -5 mA I_{OH} = -1 mA
I_{OFF} I_{OFF}	Output Off Current Output Off Current		I_F I_R		V_{OFF} = 0.45V V_{OFF} = 5.25V
V_{IL}	Input Low Voltage —A Side —B Side		0.8 0.9	V V	V_{CC} = 5.0V, See Note 1 V_{CC} = 5.0V, See Note 1
V_{IH}	Input High Voltage	2.0		V	V_{CC} = 5.0V, See Note 1
C_{IN}	Input Capacitance		12	pF	F = 1 MHz V_{BIAS} = 2.5V, V_{CC} = 5V T_A = 25°C

Note: 1. B Outputs — I_{OL} = 32 mA, I_{OH} = -5 mA, C_L = 300 pF A Outputs — I_{OL} = 10 mA, I_{OH} = -1 mA, C_L = 100 pF

A.C. CHARACTERISTICS FOR 8286/8287

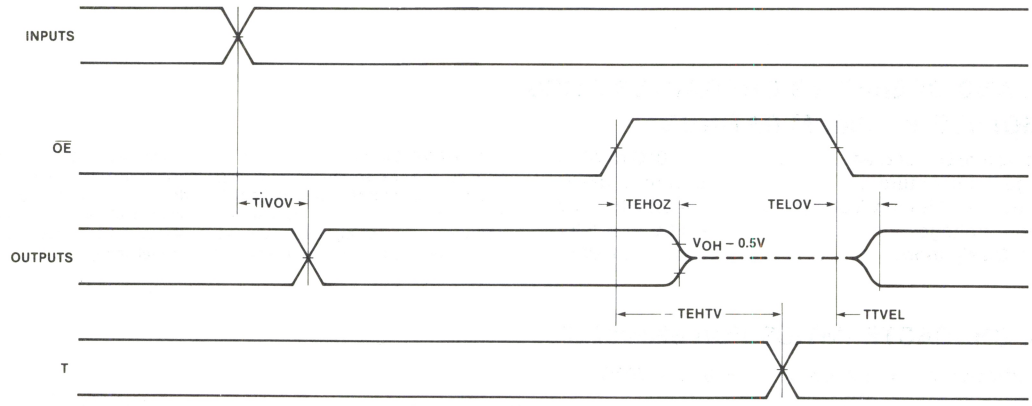
Conditions: V_{CC} = 5V ±5%, T_A = 0°C to 70°C

Loading: B Outputs — I_{OL} = 32 mA, I_{OH} = −5 mA, C_L = 300 pF
A Outputs — I_{OL} = 10 mA, I_{OH} = −1 mA, C_L = 100 pF

Symbol	Parameter	Min	Max	Units	Test Conditions
TIVOV	Input to Output Delay Inverting Non-Inverting		 25 35	 ns ns	(See Note 1)
TEHTV	Transmit/Receive Hold Time	TEHOZ		ns	
TTVEL	Transmit/Receive Setup	30		ns	
TEHOZ	Output Disable Time		25	ns	
TELOV	Output Enable Time	10	50	ns	

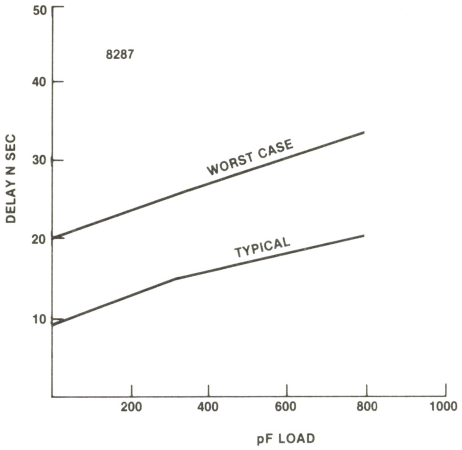
Note: 1. See waveforms and test load circuit on following page.

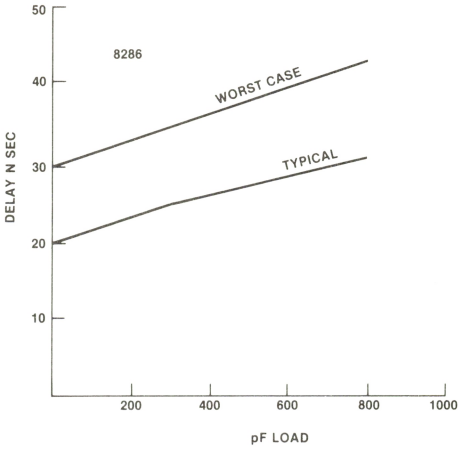
8286/8287 TIMING



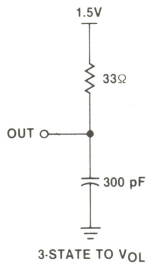
NOTE: 1. ALL TIMING MEASUREMENTS ARE MADE AT 1.5V UNLESS OTHERWISE NOTED.

OUTPUT DELAY VS. CAPACITANCE

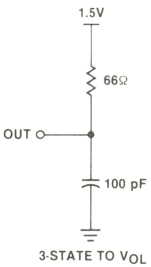




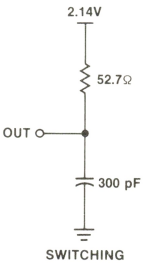
TEST LOAD CIRCUITS



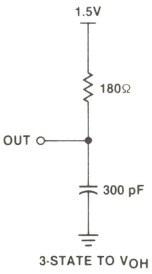
B OUTPUT



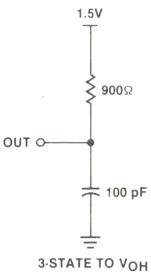
A OUTPUT



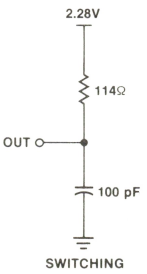
B OUTPUT



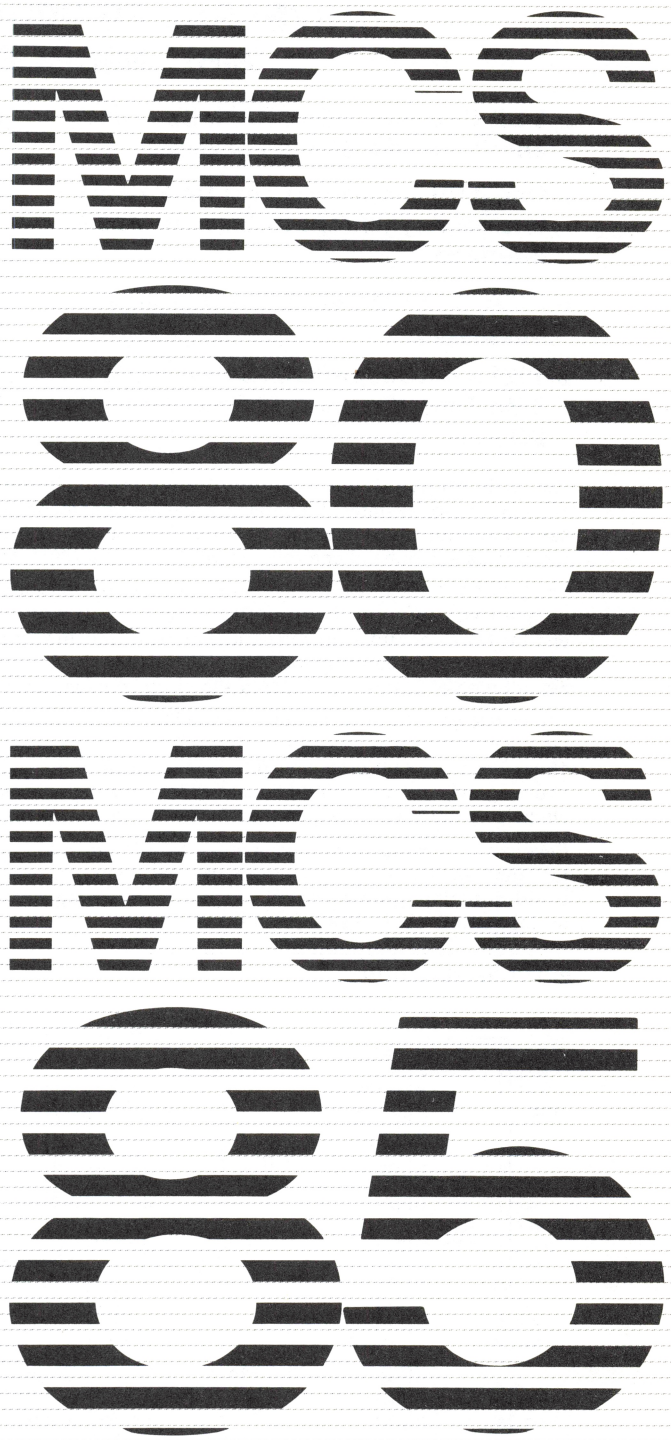
B OUTPUT



A OUTPUT



A OUTPUT



Chapter 6

MCS-85™
MCS-80™

Systems
Support
Components

Peripherals

Static RAMs

ROMs-EPROMs

8041A/8641A/8741A
UNIVERSAL PERIPHERAL INTERFACE
8-BIT MICROCOMPUTER

- 8-Bit CPU plus ROM, RAM, I/O, Timer and Clock in a Single Package
- One 8-Bit Status and Two Data Registers for Asynchronous Slave-to-Master Interface
- DMA, Interrupt, or Polled Operation Supported
- 1024 x 8 ROM/EPROM, 64 x 8 RAM, 8-Bit Timer/Counter, 18 Programmable I/O Pins
- Fully Compatible with MCS-48™, MCS-80™, MCS-85™, and MCS-86™ Microprocessor Families
- Interchangeable ROM and EPROM Versions
- 3.6 MHz 8741A-8 Available
- Expandable I/O
- RAM Power-Down Capability
- Over 90 Instructions: 70% Single Byte
- Single 5V Supply

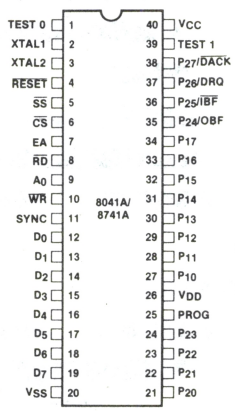
The Intel® 8041A/8741A is a general purpose, programmable interface device designed for use with a variety of 8-bit microprocessor systems. It contains a low cost microcomputer with program memory, data memory, 8-bit CPU, I/O ports, timer/counter, and clock in a single 40-pin package. Interface registers are included to enable the UPI device to function as a peripheral controller in MCS-48™, MCS-80™, MCS-85™, MCS-86™, and other 8-bit systems.

The UPI-41A™ has 1K words of program memory and 64 words of data memory on-chip. To allow full user flexibility the program memory is available as ROM in the 8041A version or as UV-erasable EPROM in the 8741A version. The 8741A and the 8041A are fully pin compatible for easy transition from prototype to production level designs. The 8641A is a one-time programmable (at the factory) 8741A which can be ordered as the first 25 pieces of a new 8041A order. The substitution of 8641A's for 8041A's allows for very fast turnaround for initial code verification and evaluation results.

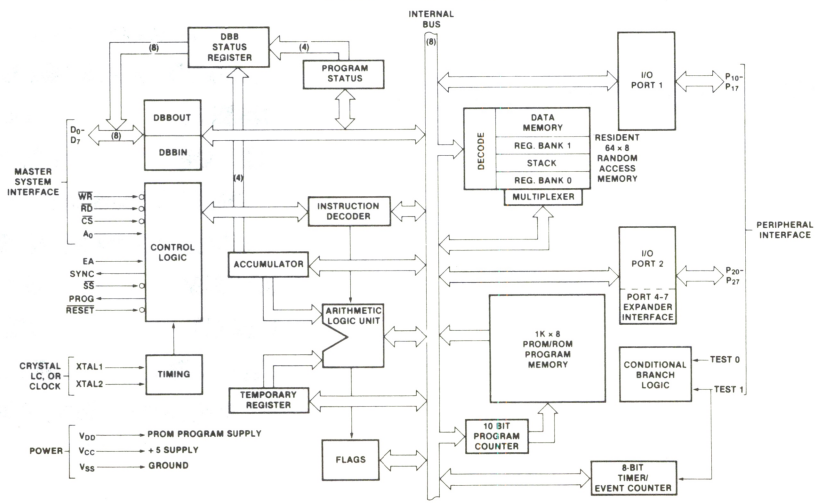
The device has two 8-bit, TTL compatible I/O ports and two test inputs. Individual port lines can function as either inputs or outputs under software control. I/O can be expanded with the 8243 device which is directly compatible and has 16 I/O lines. An 8-bit programmable timer/counter is included in the UPI device for generating timing sequences or counting external inputs. Additional UPI features include: single 5V supply, low power standby mode (in the 8041A), single-step mode for debug (in the 8741A), and dual working register banks.

Because it's a complete microcomputer, the UPI provides more flexibility for the designer than conventional LSI interface devices. It is designed to be an efficient controller as well as an arithmetic processor. Applications include keyboard scanning, printer control, display multiplexing and similar functions which involve interfacing peripheral devices to microprocessor systems.

PIN CONFIGURATION



BLOCK DIAGRAM

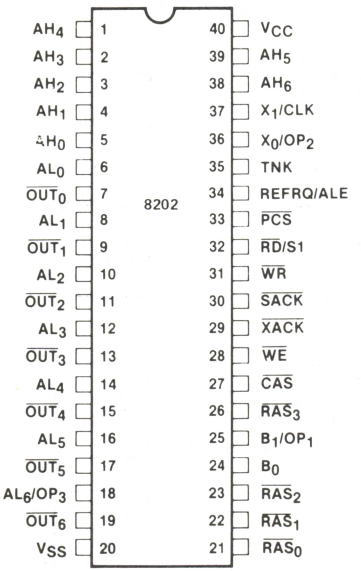


8202
DYNAMIC RAM CONTROLLER

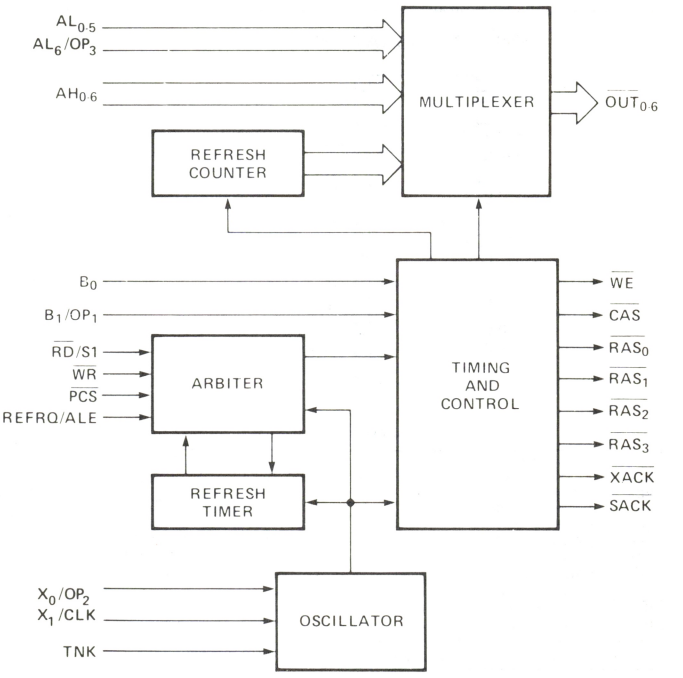
- **Provides All Signals Necessary to Control 2104A, 2117, or 2118 Dynamic Memories**
- **Directly Addresses and Drives Up to 128K Bytes Without External Drivers**
- **Provides Address Multiplexing and Strobes**
- **Provides a Refresh Timer and a Refresh Counter**
- **Refresh Cycles May be Internally or Externally Requested**
- **Provides Transparent Refresh Capability**
- **Fully Compatible with Intel® 8080A, 8085A and 8086 Microprocessors**
- **Decodes 8085A Status for Advanced Read Capability**
- **Provides System Acknowledge and Transfer Acknowledge Signals**
- **Internal or External Clock Capability**

The 8202 is a Dynamic RAM System Controller designed to provide all signals necessary to use 2104A, 2117, or 2118 Dynamic RAMs in microcomputer systems. The 8202 provides multiplexed addresses and address strobes, as well as refresh/access arbitration. Refresh cycles can be started internally or externally.

PIN CONFIGURATION



8202 BLOCK DIAGRAM



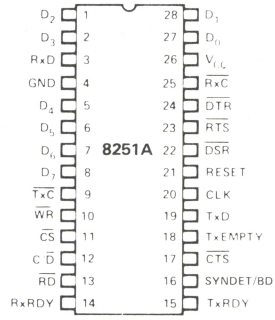
8251A
PROGRAMMABLE COMMUNICATION INTERFACE

PRELIMINARY
Notice: This is a product in development. Some parameters are subject to change.

- **Synchronous and Asynchronous Operation**
- **Synchronous 5-8 Bit Characters; Internal or External Character Synchronization; Automatic Sync Insertion**
- **Asynchronous 5-8 Bit Characters; Clock Rate—1, 16 or 64 Times Baud Rate; Break Character Generation; 1, 1½, or 2 Stop Bits; False Start Bit Detection; Automatic Break Detect and Handling.**
- **Synchronous Baud Rate — DC to 64K Baud**
- **Asynchronous Baud Rate — DC to 19.2K Baud**
- **Full Duplex, Double Buffered, Transmitter and Receiver**
- **Error Detection — Parity, Overrun and Framing**
- **Fully Compatible with 8080/8085 CPU**
- **28-Pin DIP Package**
- **All Inputs and Outputs are TTL Compatible**
- **Single +5V Supply**
- **Single TTL Clock**

The Intel® 8251A is the enhanced version of the industry standard, Intel® 8251 Universal Synchronous/Asynchronous Receiver/Transmitter (USART), designed for data communications with Intel's new high performance family of microprocessors such as the 8085. The 8251A is used as a peripheral device and is programmed by the CPU to operate using virtually any serial data transmission technique presently in use (including IBM "bi-sync"). The USART accepts data characters from the CPU in parallel format and then converts them into a continuous serial data stream for transmission. Simultaneously, it can receive serial data streams and convert them into parallel data characters for the CPU. The USART will signal the CPU whenever it can accept a new character for transmission or whenever it has received a character for the CPU. The CPU can read the complete status of the USART at any time. These include data transmission errors and control signals such as SYNDET, TxEMPTY. The chip is constructed using N-channel silicon gate technology.

PIN CONFIGURATION

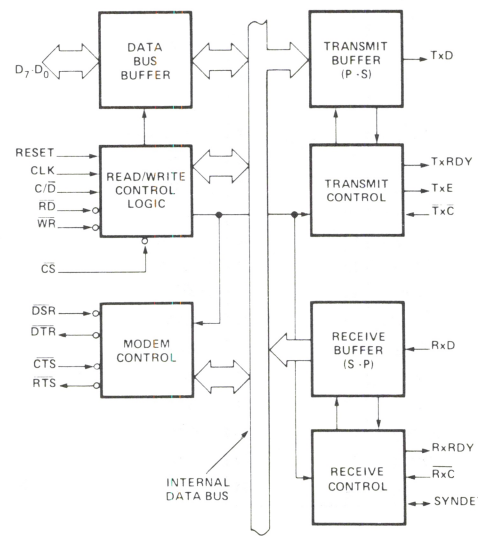


PIN NAMES

D_7-D_0	Data Bus (8 bits)
C/D	Control or Data is to be Written or Read
$\overline{RD}$	Read Data Command
$\overline{WR}$	Write Data or Control Command
$\overline{CS}$	Chip Enable
CLK	Clock Pulse (TTL)
RESET	Reset
$\overline{TxC}$	Transmitter Clock
TxD	Transmitter Data
$\overline{RxC}$	Receiver Clock
RxD	Receiver Data
RxRDY	Receiver Ready (has character for 8080)
TxRDY	Transmitter Ready (ready for char. from 8080)

$\overline{DSR}$	Data Set Ready
$\overline{DTR}$	Data Terminal Ready
SYNDET/BD	Sync Detect/ Break Detect
$\overline{RTS}$	Request to Send Data
$\overline{CTS}$	Clear to Send Data
TxE	Transmitter Empty
V_{CC}	+5 Volt Supply
GND	Ground

BLOCK DIAGRAM



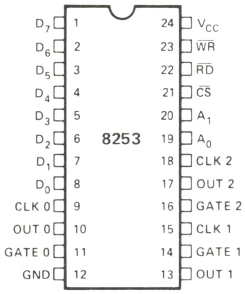
8253/8253-5
PROGRAMMABLE INTERVAL TIMER

- MCS-85™ Compatible 8253-5
- 3 Independent 16-Bit Counters
- DC to 2 MHz
- Programmable Counter Modes
- Count Binary or BCD
- Single +5V Supply
- 24-Pin Dual In-Line Package

The Intel® 8253 is a programmable counter/timer chip designed for use as an Intel microcomputer peripheral. It uses nMOS technology with a single +5V supply and is packaged in a 24-pin plastic DIP.

It is organized as 3 independent 16-bit counters, each with a count rate of up to 2 MHz. All modes of operation are software programmable.

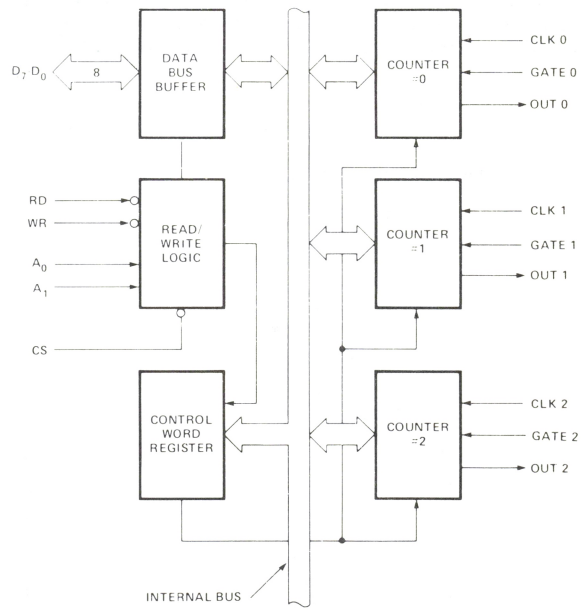
PIN CONFIGURATION



PIN NAMES

D_7 D_0	DATA BUS (8 BIT)
CLK N	COUNTER CLOCK INPUTS
GATE N	COUNTER GATE INPUTS
OUT N	COUNTER OUTPUTS
RD	READ COUNTER
WR	WRITE COMMAND OR DATA
CS	CHIP SELECT
A_0 A_1	COUNTER SELECT
V_{CC}	+5 VOLTS
GND	GROUND

BLOCK DIAGRAM

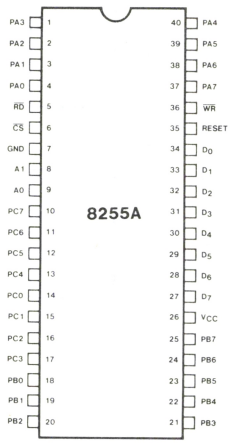


8255A/8255A-5
PROGRAMMABLE PERIPHERAL INTERFACE

- MCS-85™ Compatible 8255A-5
- 24 Programmable I/O Pins
- Completely TTL Compatible
- Fully Compatible with Intel® Microprocessor Families
- Improved Timing Characteristics
- Direct Bit Set/Reset Capability Easing Control Application Interface
- 40-Pin Dual In-Line Package
- Reduces System Package Count
- Improved DC Driving Capability

The Intel® 8255A is a general purpose programmable I/O device designed for use with Intel® microprocessors. It has 24 I/O pins which may be individually programmed in 2 groups of 12 and used in 3 major modes of operation. In the first mode (MODE 0), each group of 12 I/O pins may be programmed in sets of 4 to be input or output. In MODE 1, the second mode, each group may be programmed to have 8 lines of input or output. Of the remaining 4 pins, 3 are used for handshaking and interrupt control signals. The third mode of operation (MODE 2) is a bidirectional bus mode which uses 8 lines for a bidirectional bus, and 5 lines, borrowing one from the other group, for handshaking.

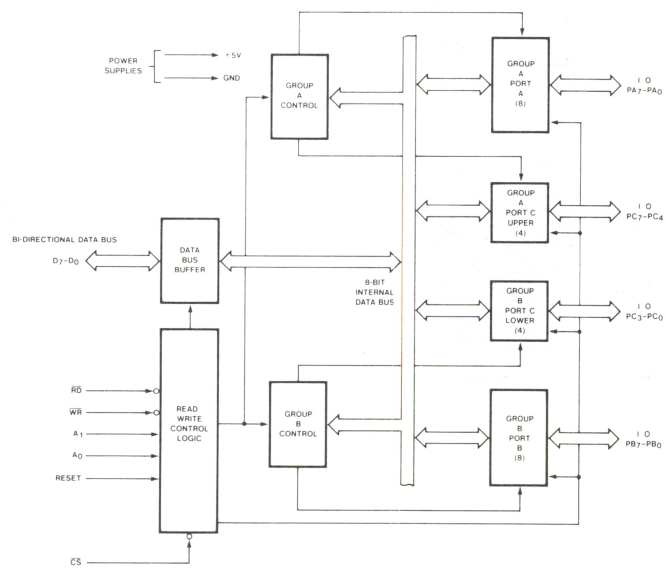
PIN CONFIGURATION



PIN NAMES

D_7-D_0	DATA BUS (BI-DIRECTIONAL)
RESET	RESET INPUT
$\overline{CS}$	CHIP SELECT
$\overline{RD}$	READ INPUT
$\overline{WR}$	WRITE INPUT
A0, A1	PORT ADDRESS
PA7-PA0	PORT A (BIT)
PB7-PB0	PORT B (BIT)
PC7-PC0	PORT C (BIT)
V_{CC}	+5 VOLTS
GND	0 VOLTS

8255A BLOCK DIAGRAM



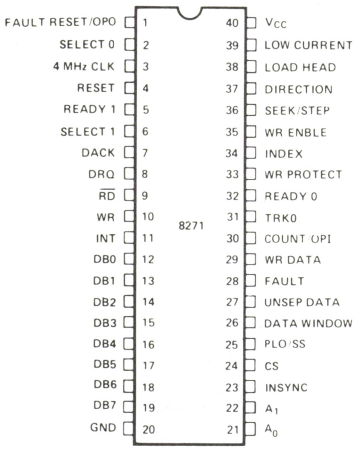
PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

8271
PROGRAMMABLE FLOPPY DISK CONTROLLER

- **IBM 3740 Soft Sectored Format Compatible**
- **Programmable Record Lengths**
- **Multi-Sector Capability**
- **Maintain Dual Drives with Minimum Software Overhead Expandable to 4 Drives**
- **Automatic Read/Write Head Positioning and Verification**
- **Internal CRC Generation and Checking**
- **Programmable Step Rate, Settle-Time, Head Load Time, Head Unload Index Count**
- **Fully MCS-80™ and MCS-85™ Compatible**
- **Single +5V Supply**
- **40-Pin Package**

The Intel® 8271 Programmable Floppy Disk Controller (FDC) is an LSI component designed to interface one to 4 floppy disk drives to an 8-bit microcomputer system. Its powerful control functions minimize both hardware and software overhead normally associated with floppy disk controllers.

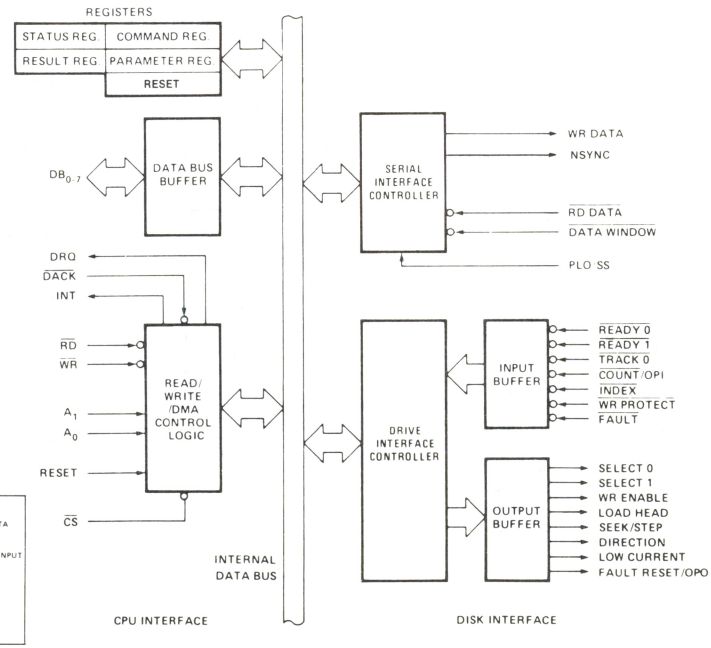
PIN CONFIGURATION



PIN NAMES

$DB_7 - DB_0$	DATA BUS (BI-DIRECTIONAL)	PLO/$\overline{SS}$	PLO/SINGLE SHOT
CLK	CLOCK INPUT (TTL)	$\overline{DATA\ WINDOW}$	DATA WINDOW
SELECT 1, 0	SELECT 1, 0	$\overline{UNSEP\ DATA}$	UNSEPARATED DATA
FAULT RESET/OPO	FAULT RESET/OPTIONAL OUTPUT	$\overline{FAULT}$	FAULT
RESET	CHIP RESET	$\overline{WR\ DATA}$	WRITE DATA
$\overline{READY}$ 1, 0	READY 1, 0	$\overline{COUNT/OPI}$	COUNT/OPTIONAL INPUT
$\overline{DACK}$	DMA ACKNOWLEDGE	$\overline{TRK\ 0}$	TRACK 0
DRQ	DMA REQUEST	$\overline{WR\ PROTECT}$	WRITE PROTECT
$\overline{RD}$	CPU READ INPUT	$\overline{INDEX}$	INDEX
$\overline{WR}$	CPU WRITE INPUT	$\overline{WR\ ENABLE}$	WRITE ENABLE
INT	INTERRUPT	SEEK/STEP	SEEK/STEP
$A_{1,0}$	REGISTER SELECT	DIRECTION	DIRECTION
INSYNC	READ DATA INSYNC	LOAD HEAD	LOAD HEAD
$\overline{CS}$	CHIP SELECT	LOW CURRENT	LOW CURRENT

BLOCK DIAGRAM

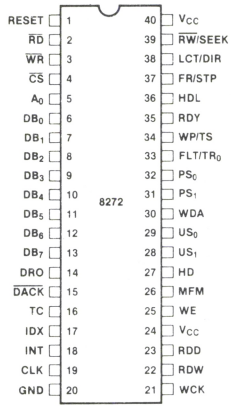


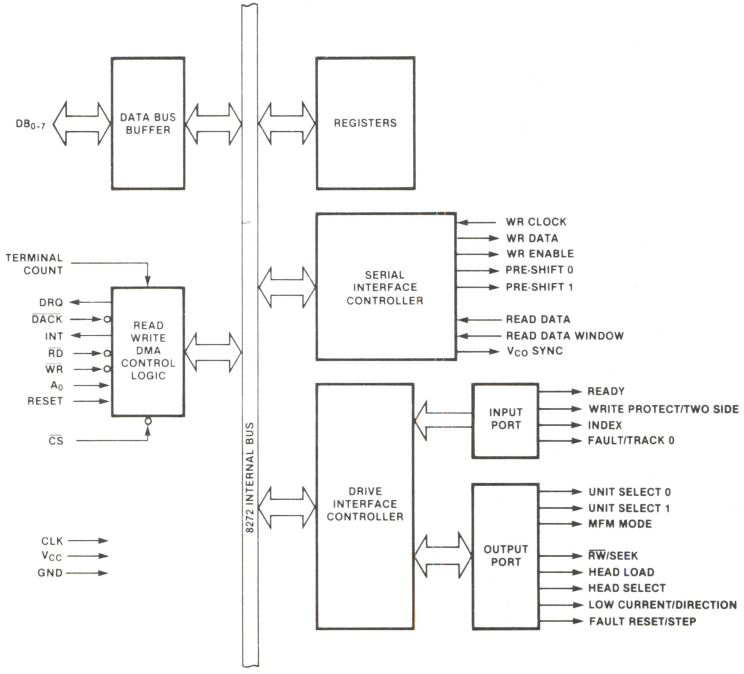
ADVANCE INFORMATION
Characteristics are subject to change without notice

8272
SINGLE/DOUBLE DENSITY FLOPPY DISK CONTROLLER

- **IBM Compatible in Both Single and Double Density Recording Formats**
- **Programmable Data Record Lengths: 128, 256, 512, or 1024 Bytes/Sector**
- **Multi-Sector and Multi-Track Transfer Capability**
- **Drive Up to 4 Floppy Disks**
- **Data Scan Capability — Will Scan a Single Sector or an Entire Cylinder's Worth of Data Fields, Comparing on a Byte by Byte Basis, Data in the Processor's Memory with Data Read from the Diskette**
- **Data Transfers in DMA or Non-DMA Mode**
- **Parallel Seek Operations on Up to Four Drives**
- **Compatible with Most Microprocessors Including 8080A, 8085A, and 8086**
- **Single Phase 8 MHz Clock**
- **Single +5 Volt Power Supply**
- **Available in 40-Pin Plastic and CERDIP Dual-in-Line Package**

The 8272 is an LSI Floppy Disk Controller (FDC) Chip, which contains the circuitry and control functions for interfacing a processor to 4 Floppy Disk Drives. It is capable of supporting either IBM 3740 single density format (FM), or IBM System 34 Double Density format (MFM) including double sided recording. The 8272 provides control signals which simplify the design of an external phase locked loop, and write precompensation circuitry. The FDC simplifies and handles most of the burdens associated with implementing a Floppy Disk Interface.



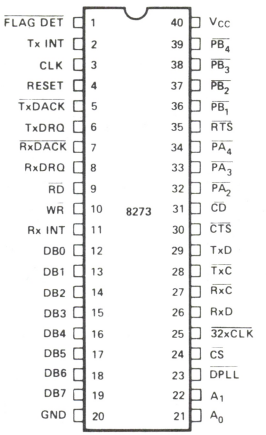


8273
PROGRAMMABLE HDLC/SDLC PROTOCOL CONTROLLER

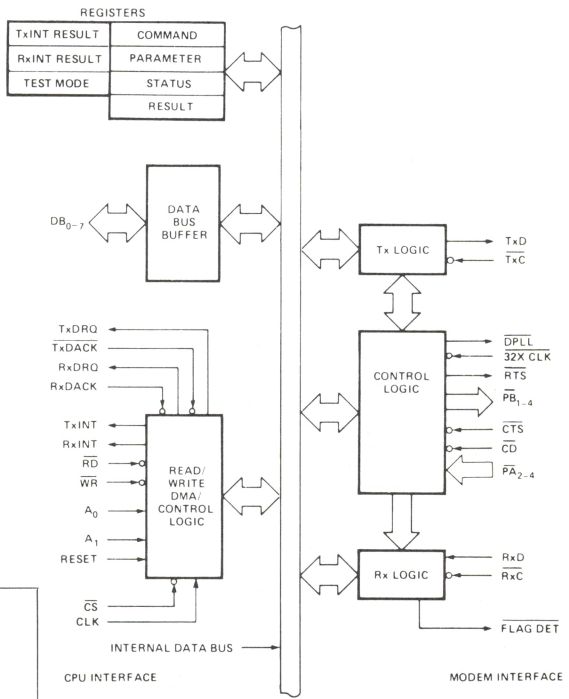
- **HDLC/SDLC Compatible**
- **Frame Level Commands**
- **Full Duplex, Half Duplex, or Loop SDLC Operation**
- **Up to 64K Baud Transfers**
- **Two User Programmable Modem Control Ports**
- **Automatic FCS (CRC) Generation and Checking**
- **Programmable NRZI Encode/Decode**
- **N-Bit Reception Capability**
- **Digital Phase Locked Loop Clock Recovery**
- **Minimum CPU Overhead**
- **Fully Compatible with 8080/8085 CPUs**
- **Single +5V Supply**
- **40-Pin Package**

The Intel® 8273 Programmable HDLC/SDLC Protocol Controller is a dedicated device designed to support the ISO/CCITT's HDLC and IBM's SDLC communication line protocols. It is fully compatible with Intel's new high performance microcomputer systems such as the MCS-85™. A frame level command set is achieved by a unique microprogrammed dual processor chip architecture. The processing capability supported by the 8273 relieves the system CPU of the low level real-time tasks normally associated with controllers.

PIN CONFIGURATION



BLOCK DIAGRAM



PIN NAMES

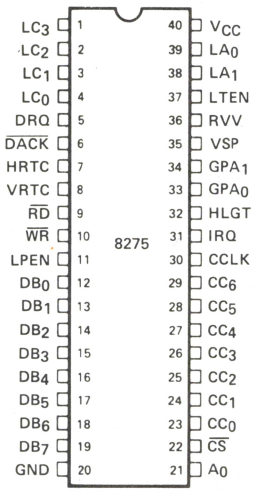
DB0–DB7	DATA BUS (8 BITS)	$\overline{CS}$	CHIP SELECT
$\overline{FLAG\ DET}$	FLAG DETECT	$\overline{32xCLK}$	32 TIMES CLOCK
TxINT	TRANSMITTER INTERRUPT	Rx D	RECEIVER DATA
CLK	CLOCK INPUT	$\overline{Rx\ C}$	RECEIVER CLOCK
$\overline{RESET}$	RESET	$\overline{Tx\ C}$	TRANSMITTER CLOCK
$\overline{Tx\ DACK}$	TRANSMITTER DMA ACKNOWLEDGE	Tx D	TRANSMITTER DATA
TxDRQ	TRANSMITTER DMA REQUEST	$\overline{CTS}$	CLEAR TO SEND
$\overline{RD}$	READ INPUT	$\overline{CD}$	CARRIER DETECT
$\overline{WR}$	WRITE INPUT	$\overline{PA_2}$–$\overline{PA_4}$	GP INPUT PORTS
$\overline{Rx\ DACK}$	RECEIVER DMA ACKNOWLEDGE	$\overline{PB_1}$–$\overline{PB_4}$	GP OUTPUT PORTS
Rx DRQ	RECEIVER DMA REQUEST	$\overline{RTS}$	REQUEST TO SEND
Rx INT	RECEIVER INTERRUPT	V_{CC}	+5 VOLT SUPPLY
A0–A1	COMMAND REGISTER SELECT ADDRESS	GND	GROUND
$\overline{DPLL}$	DIGITAL PHASE LOCKED LOOP		

8275
PROGRAMMABLE CRT CONTROLLER

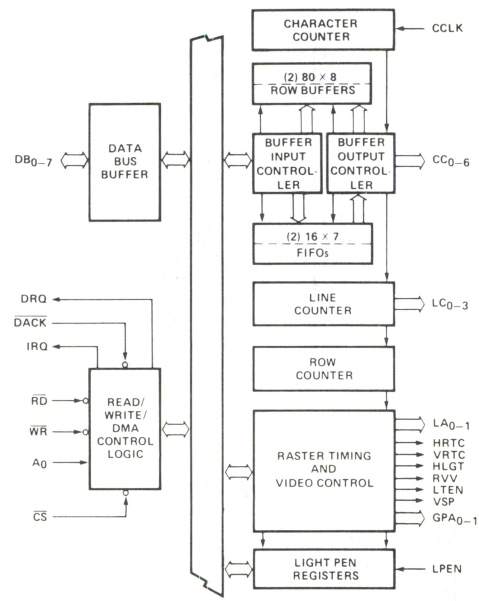
- **Programmable Screen and Character Format**
- **6 Independent Visual Field Attributes**
- **11 Visual Character Attributes (Graphic Capability)**
- **Cursor Control (4 Types)**
- **Light Pen Detection and Registers**
- **Fully MCS-80™ and MCS-85™ Compatible**
- **Dual Row Buffers**
- **Programmable DMA Burst Mode**
- **Single +5V Supply**
- **40-Pin Package**

The Intel® 8275 Programmable CRT Controller is a single chip device to interface CRT raster scan displays with Intel® microcomputer systems. Its primary function is to refresh the display by buffering the information from main memory and keeping track of the display position of the screen. The flexibility designed into the 8275 will allow simple interface to almost any raster scan CRT display with a minimum of external hardware and software overhead.

PIN CONFIGURATION



BLOCK DIAGRAM



PIN NAMES

DB_{0-1}	BI-DIRECTIONAL DATA BUS	LC_{0-3}	LINE COUNTER OUTPUTS
DRQ	DMA REQUEST OUTPUT	LA_{0-1}	LINE ATTRIBUTE OUTPUTS
$\overline{DACK}$	DMA ACKNOWLEDGE INPUT	HRTC	HORIZONTAL RETRACE OUTPUT
IRQ	INTERRUPT REQUEST OUTPUT	VRTC	VERTICAL RETRACE OUTPUT
$\overline{RD}$	READ STROBE INPUT	HLGT	HIGHLIGHT OUTPUT
$\overline{WR}$	WRITE STROBE INPUT	RVV	REVERSE VIDEO OUTPUT
A_0	REGISTER ADDRESS INPUT	LTEN	LIGHT ENABLE OUTPUT
$\overline{CS}$	CHIP SELECT INPUT	VSP	VIDEO SUPPRESS OUTPUT
CCLK	CHARACTER CLOCK INPUT	GPA_{0-1}	GENERAL PURPOSE ATTRIBUTE OUTPUTS
CC_{0-6}	CHARACTER CODE OUTPUTS	LPEN	LIGHT PEN INPUT

PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

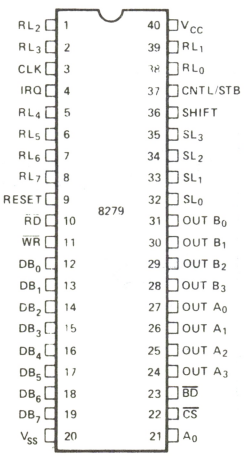
8279/8279-5
PROGRAMMABLE KEYBOARD/DISPLAY INTERFACE

- MCS-85™ Compatible 8279-5
- Simultaneous Keyboard Display Operations
- Scanned Keyboard Mode
- Scanned Sensor Mode
- Strobed Input Entry Mode
- 8-Character Keyboard FIFO
- 2-Key Lockout or N-Key Rollover with Contact Debounce
- Dual 8- or 16-Numerical Display
- Single 16-Character Display
- Right or Left Entry 16-Byte Display RAM
- Mode Programmable from CPU
- Programmable Scan Timing
- Interrupt Output on Key Entry

The Intel® 8279 is a general purpose programmable keyboard and display I/O interface device designed for use with Intel® microprocessors. The keyboard portion can provide a scanned interface to a 64-contact key matrix. The keyboard portion will also interface to an array of sensors or a strobed interface keyboard, such as the hall effect and ferrite variety. Key depressions can be 2-key lockout or N-key rollover. Keyboard entries are debounced and strobed in an 8-character FIFO. If more than 8 characters are entered, overrun status is set. Key entries set the interrupt output line to the CPU.

The display portion provides a scanned display interface for LED, incandescent, and other popular display technologies. Both numeric and alphanumeric segment displays may be used as well as simple indicators. The 8279 has 16X8 display RAM which can be organized into dual 16X4. The RAM can be loaded or interrogated by the CPU. Both right entry, calculator and left entry typewriter display formats are possible. Both read and write of the display RAM can be done with auto-increment of the display RAM address.

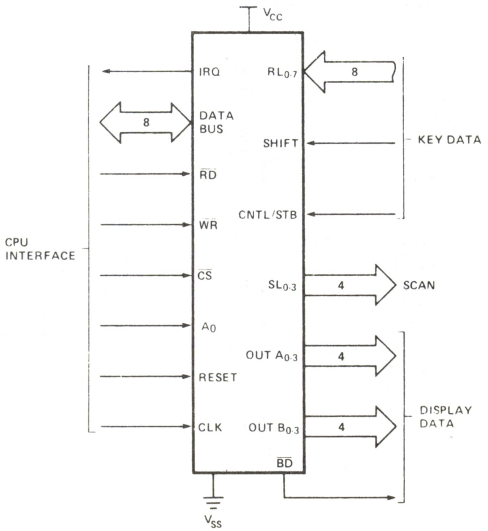
PIN CONFIGURATION



PIN NAMES

DB_{0-7}	I/O	DATA BUS (BI DIRECTIONAL)
CLK	I	CLOCK INPUT
RESET	I	RESET INPUT
$\overline{CS}$	I	CHIP SELECT
$\overline{RD}$	I	READ INPUT
$\overline{WR}$	I	WRITE INPUT
A_0	I	BUFFER ADDRESS
IRQ	O	INTERRUPT REQUEST OUTPUT
SL_{0-3}	O	SCAN LINES
RL_{0-7}	I	RETURN LINES
SHIFT	I	SHIFT INPUT
CNTL/STB	I	CONTROL/STROBE INPUT
$OUT\ A_{0-3}$	O	DISPLAY (A) OUTPUTS
$OUT\ B_{0-3}$	O	DISPLAY (B) OUTPUTS
$\overline{BD}$	O	BLANK DISPLAY OUTPUT

LOGIC SYMBOL



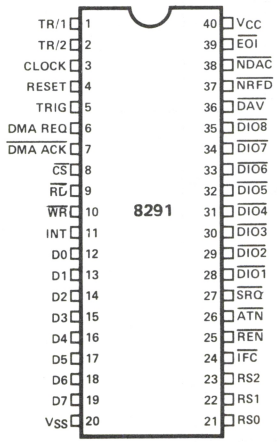
PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

8291
GPIB TALKER/LISTENER

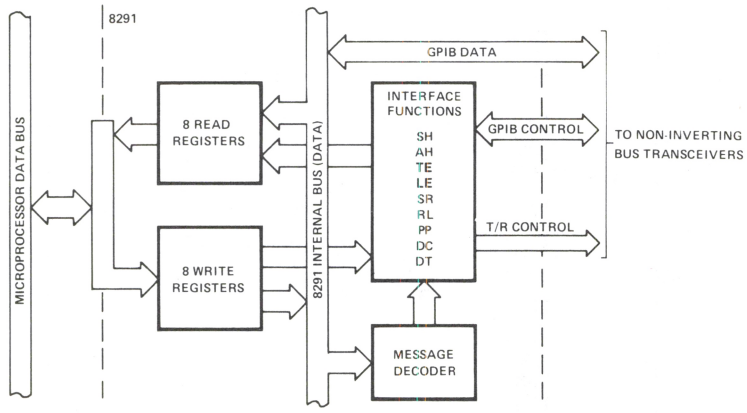
- Designed to Interface Microprocessors (e.g., 8080, 8085, 8086, 8048) to an IEEE Standard 488 Digital Interface Bus
- Programmable Data Transfer Rate
- Complete Source and Acceptor Handshake
- Complete Talker and Listener Functions with Extended Addressing
- Service Request, Parallel Poll, Device Clear, Device Trigger, Remote/Local Functions
- Selectable Interrupts
- On-Chip Primary and Secondary Address Recognition
- Automatic Handling of Addressing and Handshake Protocol
- Provision for Software Implementation of Additional Features
- 1 – 8 MHz Clock Range
- 16 Registers (8 Read, 8 Write), 2 for Data Transfer, the Rest for Interface Function Control, Status, etc.
- Directly Interfaces to External Non-Inverting Transceivers for Connection to the GPIB
- Provides Three Addressing Modes, Allowing the Chip to be Addressed Either as a Major or a Minor Talker/Listener with Primary or Secondary Addressing
- DMA Handshake Provision Allows for Bus Transfers without CPU Intervention
- Trigger Output Pin
- On-Chip EOS (End of Sequence) Message Recognition Facilitates Handling of Multi-Byte Transfers

The 8291 GPIB Talker/Listener is a microprocessor-controlled chip designed to interface microprocessors (e.g., 8048, 8080, 8085, 8086) to an IEEE Standard 488 Instrumentation Interface Bus. It implements all of the Standard's interface functions except for the controller.

PIN CONFIGURATION



BLOCK DIAGRAM



PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

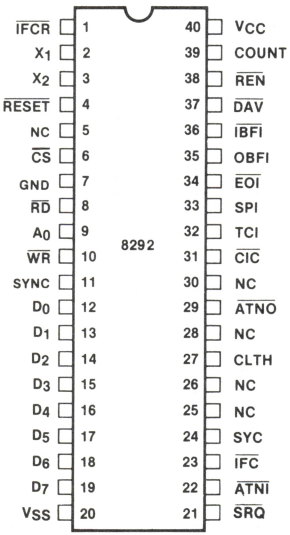
8292
GPIB CONTROLLER

FEATURES:

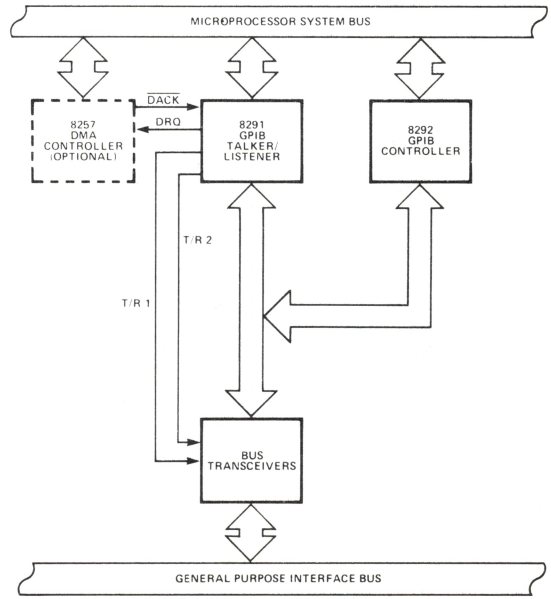
- **Complete IEEE Standard 488 Controller Function.**
- **Interface Clear (IFC) Sending Capability Allows for Seizure of Control and/or Initialization of the Bus.**
- **Responds to Service Requests (SRQ).**
- **Sends (REN), Allowing Instruments to Switch to Remote Control.**
- **Complete Implementation of Transfer Control Protocol.**
- **Synchronous Control Seizure Prevents the Destruction of any Data Transmission in Progress.**
- **Connects with the 8291 to Form a Complete IEEE Standard 488 Interface Talker/Listener/Controller.**

The 8292 GPIB CONTROLLER is a microprocessor-controlled chip designed to connect with the 8291 GPIB TALKER/LISTENER to implement the full IEEE Standard 488 controller function, including transfer control protocol. The 8292 is a pre-programmed UPI-41A.™

PIN CONFIGURATION



8291, 8292 SYSTEM DIAGRAM



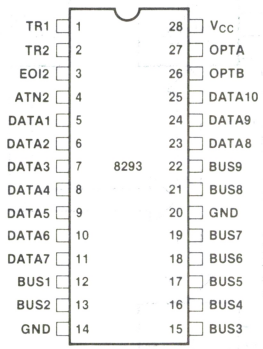
ADVANCE INFORMATION
Characteristics are subject to change without notice.

8293
GPIB TRANSCEIVER

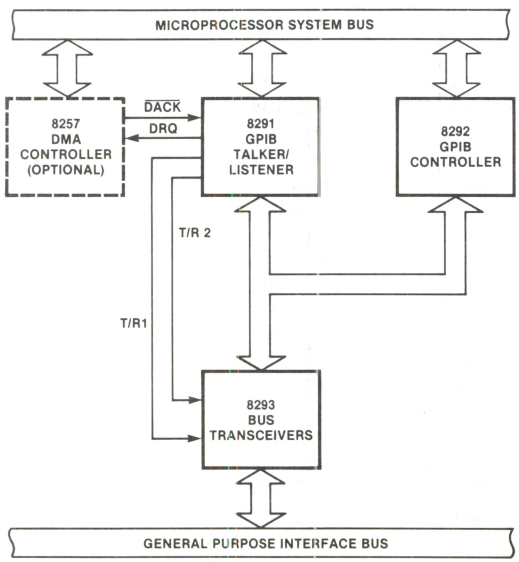
- Nine Open-collector or Three-state Line Drivers
- 48 mA Sink Current Capability on Each Line Driver
- Nine Schmitt-type Line Receivers
- High Capacitance Load Drive Capability
- Single 5V Power Supply
- 28-Pin Package
- Low Power HMOS Design
- On-chip Decoder for Mode Configuration
- Power Up/Power Down Protection to Prevent Disrupting the IEEE Bus
- Connects with the 8291 and 8292 to Form an IEEE Standard 488 Interface Talker/Listener/Controller with no Additional Components
- Only Two 8293's Required per GPIB Interface

The Intel® 8293 GPIB Transceiver is a high current, non-inverting buffer chip designed to interface the 8291 GPIB Talker/Listener or the 8292 GPIB Controller with the 8291 to the IEEE Standard 488-1978 Instrumentation Interface Bus. Each GPIB interface would contain two 8293 Bus Transceivers. In addition, the 8293 can also be used as a general purpose bus driver.

PIN CONFIGURATION



8291, 8292, 8293 SYSTEM DIAGRAM



PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

8294
DATA ENCRYPTION UNIT

- Certified by National Bureau of Standards
- 80 Byte/Sec Data Conversion Rate
- 64-Bit Data Encryption Using 56-Bit Key
- DMA Interface
- 3 Interrupt Outputs to Aid in Loading and Unloading Data
- 7-Bit User Output Port
- Single 5V ± 10% Power Supply
- Peripheral to MCS-86™, MCS-85™, MCS-80™ and MCS-48™ Processors
- Implements Federal Information Processing Data Encryption Standard
- Encrypt and Decrypt Modes Available

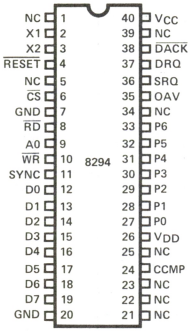
DESCRIPTION

The Intel® 8294 Data Encryption Unit (DEU) is a microprocessor peripheral device designed to encrypt and decrypt 64-bit blocks of data using the algorithm specified in the Federal Information Processing Data Encryption Standard. The DEU operates on 64-bit text words using a 56-bit user-specified key to produce 64-bit cipher words. The operation is reversible: if the cipher word is operated upon, the original text word is produced. The algorithm itself is permanently contained in the 8294; however, the 56-bit key is user-defined and may be changed at any time.

The 56-bit key and 64-bit message data are transferred to and from the 8294 in 8-bit bytes by way of the system data bus. A DMA interface and three interrupt outputs are available to minimize software overhead associated with data transfer. Also, by using the DMA interface two or more DEUs may be operated in parallel to achieve effective system conversion rates which are virtually any multiple of 80 bytes/second. The 8294 also has a 7-bit TTL compatible output port for user-specified functions.

Because the 8294 implements the NBS encryption algorithm it can be used in a variety of Electronic Funds Transfer applications as well as other electronic banking and data handling applications where data must be encrypted.

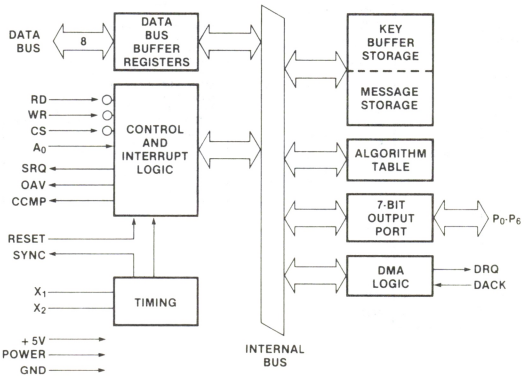
PIN CONFIGURATION



PIN NAMES

PIN NAME	FUNCTION
D_7-D_0	DATA BUS
$\overline{RD}$,$\overline{WR}$	READ,WRITE STROBES
$\overline{CS}$	CHIP SELECT
A_0	CONTROL/DATA SELECT
$\overline{RESET}$	RESET INPUT
X_1,X_2	FREQUENCY REFERENCE INPUT
SYNC	HIGH FREQUENCY OUTPUT
DRQ,$\overline{DACK}$	DMA REQUEST,DMA ACKNOWLEDGE
SRQ,OAV,CCMP	INTERRUPT REQUEST OUTPUTS
P_6-P_0	OUTPUT PORT LINES
V_{CC},V_{DD},GND	+5V POWER,GND
NC	NO CONNECTION

BLOCK DIAGRAM



PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

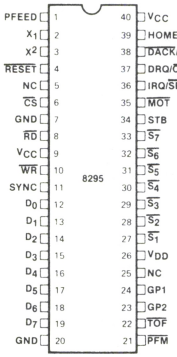
8295
DOT MATRIX PRINTER CONTROLLER

- **Interfaces Dot Matrix Printers to MCS-48™, MCS-80/85™, MCS-86™ Systems**
- **40 Character Buffer On Chip**
- **Serial or Parallel Communication with Host**
- **DMA Transfer Capability**
- **Programmable Character Density (10 or 12 Chararcters/Inch)**
- **Programmable Print Intensity**
- **Single or Double Width Printing**
- **Programmable Multiple Line Feeds**
- **3 Tabulations**
- **2 General Purpose Outputs**

The Intel® 8295 Dot Matrix Printer Controller provides an interface for microprocessors to the LRC 7040 Series dot matrix impact printers. It may also be used as an interface to other similar printers.

The chip may be used in a serial or parallel communication mode with the host processor. In parallel mode, data transfers are based on polling, interrupts, or DMA. Furthermore, it provides internal buffering of up to 40 characters and contains a 7 × 7 matrix character generator accommodating 64 ASCII characters.

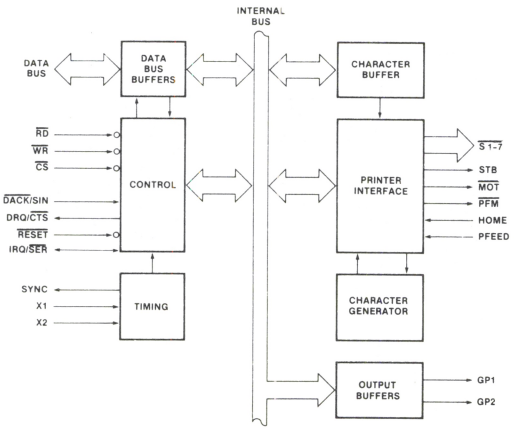
PIN CONFIGURATION



PIN NAMES

PIN NAME	FUNCTION
D_0-D_7	DATA BUS
RD, WR	READ, WRITE STROBES
CS	CHIP SELECT
RESET	RESET INPUT
X_1, X_2	FREQUENCY REFERENCE INPUTS
SYNC	HIGH FREQUENCY OUTPUT
MOT, PFM	MAIN, PAPER FEED MOTOR DRIVES
DRQ, DACK	DMA REQUEST, ACKNOWLEDGE
SIN, CTS	SERIAL INPUT, CLEAR-TO-SEND
IRQ/SER	INTERRUPT REQUEST, SERIAL GROUND
S_1-S_7	SOLENOID DRIVE OUTPUTS
PFEED	PAPER FEED INPUT
HOME, TOF	HOME, TOP-OF-FORM INPUTS
STB	SOLENOID STROBE OUTPUT
GP1, GP2	GENERAL PURPOSE OUTPUTS
VCC, VDD, GND	+5V POWER, GND

BLOCK DIAGRAM



Chapter 6

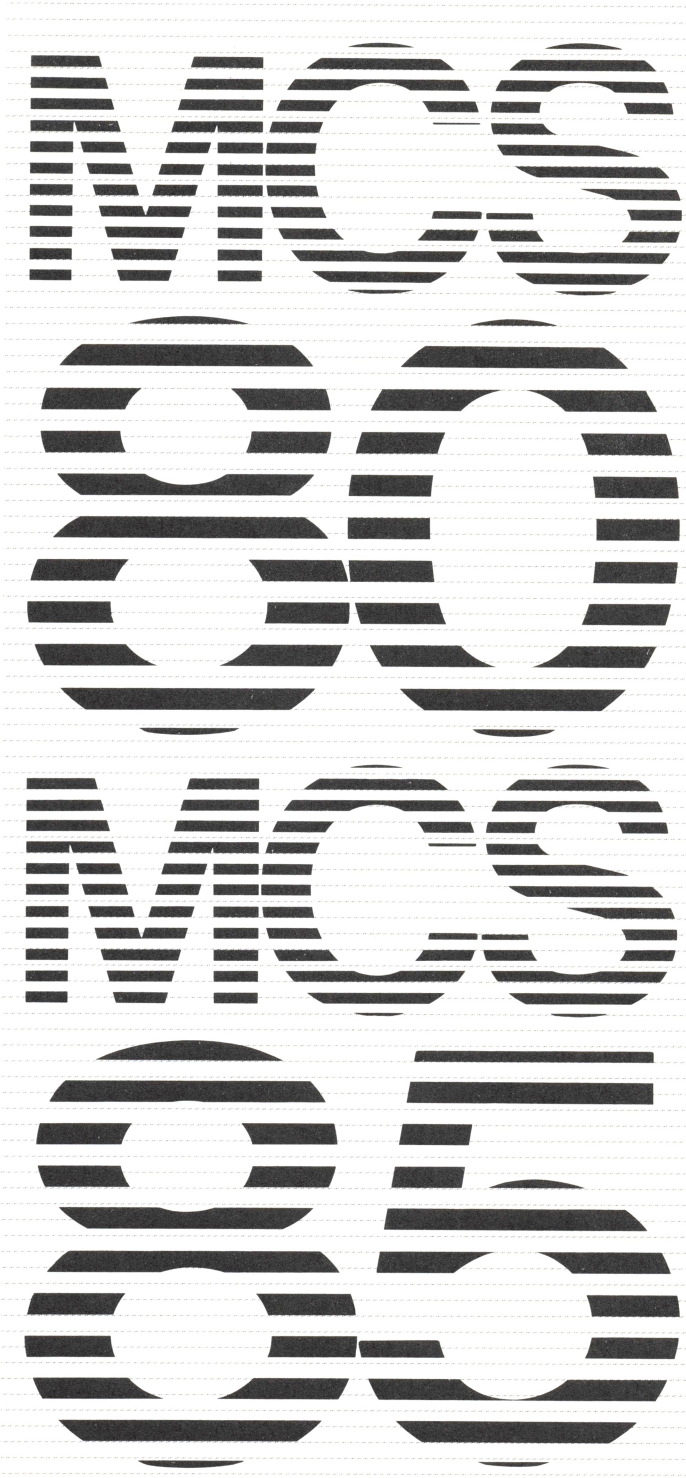
MCS-85™
MCS-80™

Systems
Support
Components

Peripherals

Static RAMs

ROMs-EPROMs



2114A
1024 X 4 BIT STATIC RAM

	2114AL-2	2114AL-3	2114AL-4	2114A-4	2114A-5
Max. Access Time (ns)	120	150	200	200	250
Max. Current (mA)	40	40	40	70	70

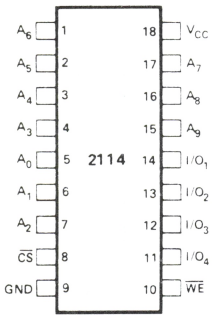
- **HMOS Technology**
- **Low Power, High Speed**
- **Identical Cycle and Access Times**
- **Single +5V Supply ±10%**
- **High Density 18 Pin Package**
- **Completely Static Memory - No Clock or Timing Strobe Required**
- **Directly TTL Compatible: All Inputs and Outputs**
- **Common Data Input and Output Using Three-State Outputs**
- **2114 Replacement**

The Intel 2114A is a 4096-bit static Random Access Memory organized as 1024 words by 4-bits using HMOS, a high performance MOS technology. It uses fully DC stable (static) circuitry throughout, in both the array and the decoding, therefore it requires no clocks or refreshing to operate. Data access is particularly simple since address setup times are not required. The data is read out nondestructively and has the same polarity as the input data. Common input/output pins are provided.

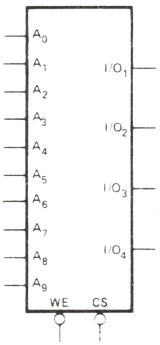
The 2114A is designed for memory applications where the high performance and high reliability of HMOS, low cost, large bit storage, and simple interfacing are important design objectives. The 2114A is placed in an 18-pin package for the highest possible density.

It is directly TTL compatible in all respects: inputs, outputs, and a single +5V supply. A separate Chip Select ($\overline{CS}$) lead allows easy selection of an individual package when outputs are or-tied.

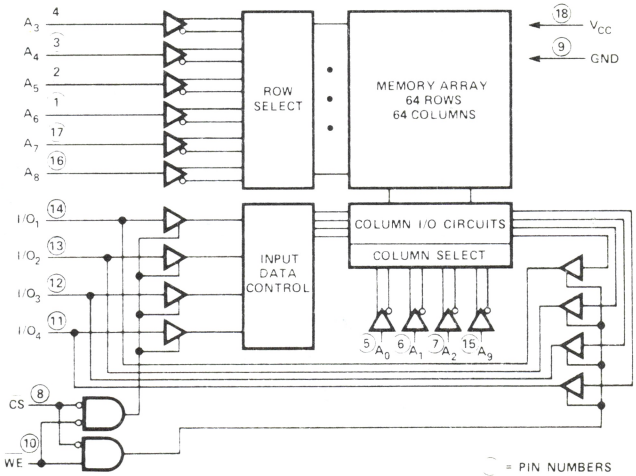
PIN CONFIGURATION



LOGIC SYMBOL



BLOCK DIAGRAM



PIN NAMES

A_0–A_9	ADDRESS INPUTS	V_{CC} POWER (+5V)
$\overline{WE}$	WRITE ENABLE	GND GROUND
$\overline{CS}$	CHIP SELECT	
I/O_1–I/O_4	DATA INPUT/OUTPUT	

2141
4096 X 1 BIT STATIC RAM

	2141-2	2141-3	2141-4	2141-5	2141L-3	2141L-4	2141L-5
Max. Access Time (ns)	120	150	200	250	150	200	250
Max. Active Current (mA)	70	70	55	55	40	40	40
Max. Standby Current (mA)	20	20	12	12	5	5	5

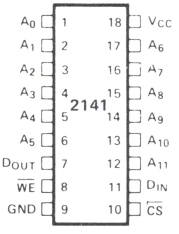
- **HMOS Technology**
- **Industry Standard 2147 Pinout**
- **Completely Static Memory — No Clock or Timing Strobe Required**
- **Equal Access and Cycle Times**
- **Single +5V Supply**
- **Automatic Power-Down**
- **Directly TTL Compatible — All Inputs and Output**
- **Separate Data Input and Output**
- **Three-State Output**
- **High Density 18-Pin Package**

The Intel® 2141 is a 4096-bit static Random Access Memory organized as 4096 words by 1-bit using HMOS, a high-performance MOS technology. It uses a uniquely innovative design approach which provides the ease-of-use features associated with non-clocked static memories and the reduced standby power dissipation associated with clocked static memories. To the user this means low standby power dissipation without the need for clocks, address setup and hold times, nor reduced data rates due to cycle times that are longer than access times.

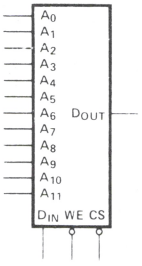
$\overline{CS}$ controls the power-down feature. In less than a cycle time after $\overline{CS}$ goes high — deselecting the 2141 — the part automatically reduces its power requirements and remains in this low power standby mode as long as $\overline{CS}$ remains high. This device feature results in system power savings as great as 85% in larger systems, where the majority of devices are de-selected.

The 2141 is placed in an 18-pin package configured with the industry standard pinout, the same as the 2147. It is directly TTL compatible in all respects: inputs, output, and a single +5V supply. The data is read out nondestructively and has the same polarity as the input data. A data input and a separate three-state output are used.

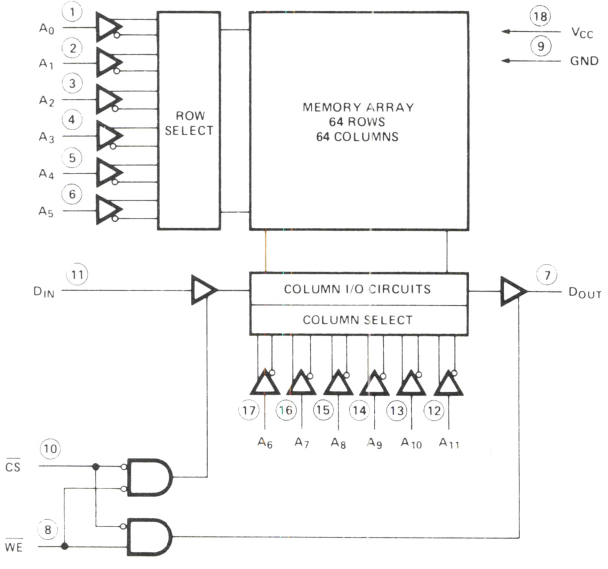
PIN CONFIGURATION



LOGIC SYMBOL



BLOCK DIAGRAM



PIN NAMES

A_0–A_{11}	ADDRESS INPUTS	V_{CC}	POWER (+5V)
$\overline{WE}$	WRITE ENABLE	GND	GROUND
$\overline{CS}$	CHIP SELECT		
D_{IN}	DATA INPUT		
D_{OUT}	DATA OUTPUT		

TRUTH TABLE

$\overline{CS}$	$\overline{WE}$	MODE	OUTPUT	POWER
H	X	NOT SELECTED	HIGH Z	STANDBY
L	L	WRITE	HIGH Z	ACTIVE
L	H	READ	D_{OUT}	ACTIVE

2142
1024 X 4 BIT STATIC RAM

	2142-2	2142-3	2142	2142L2	2142L3	2142L
Max. Access Time (ns)	200	300	450	200	300	450
Max. Power Dissipation (mw)	525	525	525	370	370	370

- **High Density 20 Pin Package**
- **Access Time Selections From 200-450ns**
- **Identical Cycle and Access Times**
- **Low Operating Power Dissipation .1mW/Bit Typical**
- **Single +5V Supply**
- **No Clock or Timing Strobe Required**
- **Completely Static Memory**
- **Directly TTL Compatible: All Inputs and Outputs**
- **Common Data Input and Output Using Three-State Outputs**

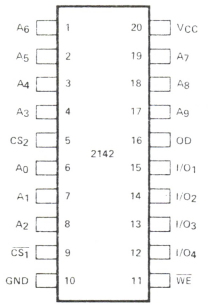
The Intel® 2142 is a 4096-bit static Random Access Memory organized as 1024 words by 4-bits using N-channel Silicon-Gate MOS technology. It uses fully DC stable (static) circuitry throughout — in both the array and the decoding — and therefore requires no clocks or refreshing to operate. Data access is particularly simple since address setup times are not required. The data is read out nondestructively and has the same polarity as the input data. Common input/output pins are provided.

The 2142 is designed for memory applications where high performance, low cost, large bit storage, and simple interfacing are important design objectives. It is directly TTL compatible in all respects: inputs, outputs, and a single +5V supply.

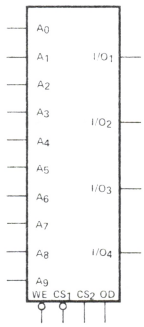
The 2142 is placed in a 20-pin package. Two Chip Selects ($\overline{CS}_1$ and CS_2) are provided for easy and flexible selection of individual packages when outputs are OR-tied. An Output Disable is included for direct control of the output buffers.

The 2142 is fabricated with Intel's N-channel Silicon-Gate technology — a technology providing excellent protection against contamination permitting the use of low cost plastic packaging.

PIN CONFIGURATION



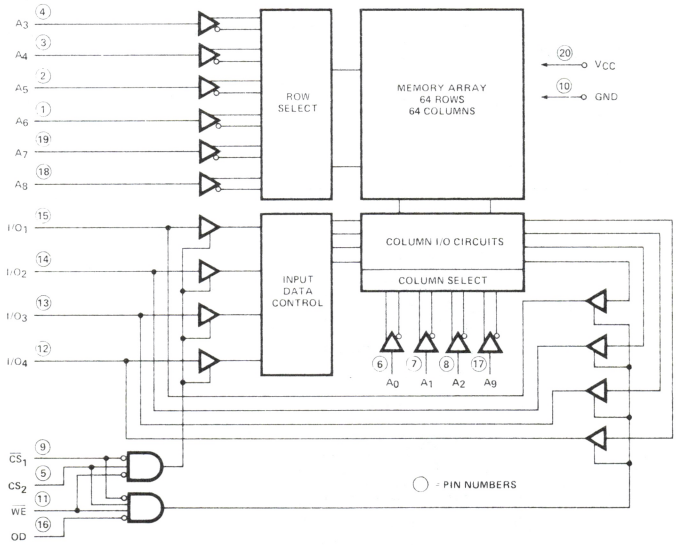
LOGIC SYMBOL



PIN NAMES

A_0–A_9	ADDRESS INPUTS	OD	OUTPUT DISABLE
$\overline{WE}$	WRITE ENABLE	V_{CC}	POWER (+5V)
$\overline{CS}_1$, CS_2	CHIP SELECT	GND	GROUND
I/O_1–I/O_4	DATA INPUT/OUTPUT		

BLOCK DIAGRAM



2148
1024 x 4 BIT STATIC RAM

	2148-3	2148	2148-6
Max. Access Time (ns)	55	70	85
Max. Active Current (mA)	125	125	125
Max. Standby Current (mA)	30	30	30

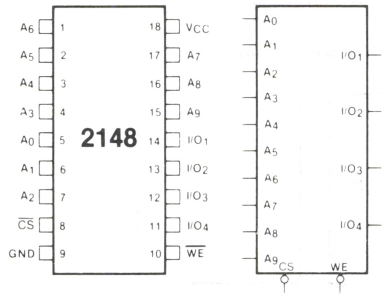
- **HMOS Technology**
- **Completely Static Memory — No Clock or Timing Strobe Required**
- **Equal Access and Cycle Times**
- **Single +5V Supply**
- **Automatic Power-Down**
- **High Density 18-Pin Package**
- **Directly TTL Compatible — All Inputs and Outputs**
- **Common Data Input and Output**
- **Three-State Output**

The Intel® 2148 is a 4096-bit static Random Access Memory organized as 1024 words by 4 bits using HMOS, a high-performance MOS technology. It uses a uniquely innovative design approach which provides the ease-of-use features associated with non-clocked static memories and the reduced standby power dissipation associated with clocked static memories. To the user this means low standby power dissipation without the need for clocks, address setup and hold times, nor reduced data rates due to cycle times that are longer than access times.

$\overline{CS}$ controls the power-down feature. In less than a cycle time after $\overline{CS}$ goes high — disabling the 2148 — the part automatically reduces its power requirements and remains in this low power standby mode as long as $\overline{CS}$ remains high. This device feature results in system power savings as great as 85% in larger systems, where the majority of devices are disabled.

The 2148 is assembled in an 18-pin package configured with the industry standard 1K x 4 pinout. It is directly TTL compatible in all respects: inputs, outputs, and a single +5V supply. The data is read out nondestructively and has the same polarity as the input data.

PIN CONFIGURATION



LOGIC SYMBOL

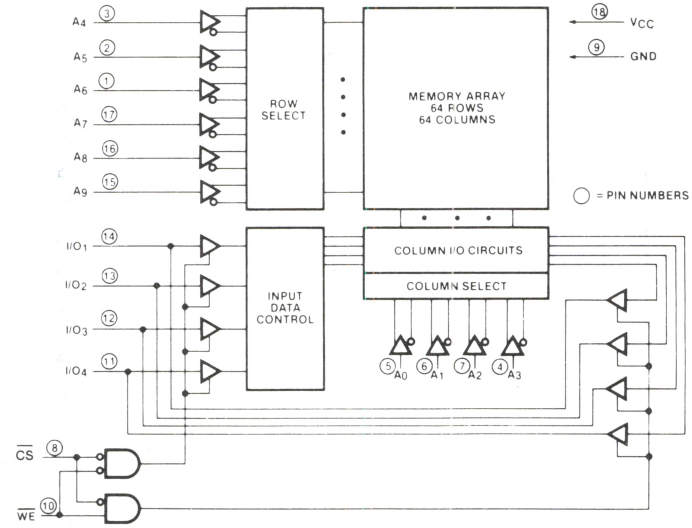
PIN NAMES

A_0 - A_9	ADDRESS INPUTS
$\overline{WE}$	WRITE ENABLE
$\overline{CS}$	CHIP SELECT
I/O_1 - I/O_4	DATA INPUT/OUTPUT
V_{CC}	POWER (+5V)
GND	GROUND

TRUTH TABLE

$\overline{CS}$	$\overline{WE}$	MODE	I/O	POWER
H	X	NOT SELECTED	HIGH-Z	STANDBY
L	L	WRITE	D_{IN}	ACTIVE
L	H	READ	D_{OUT}	ACTIVE

BLOCK DIAGRAM



Chapter 6

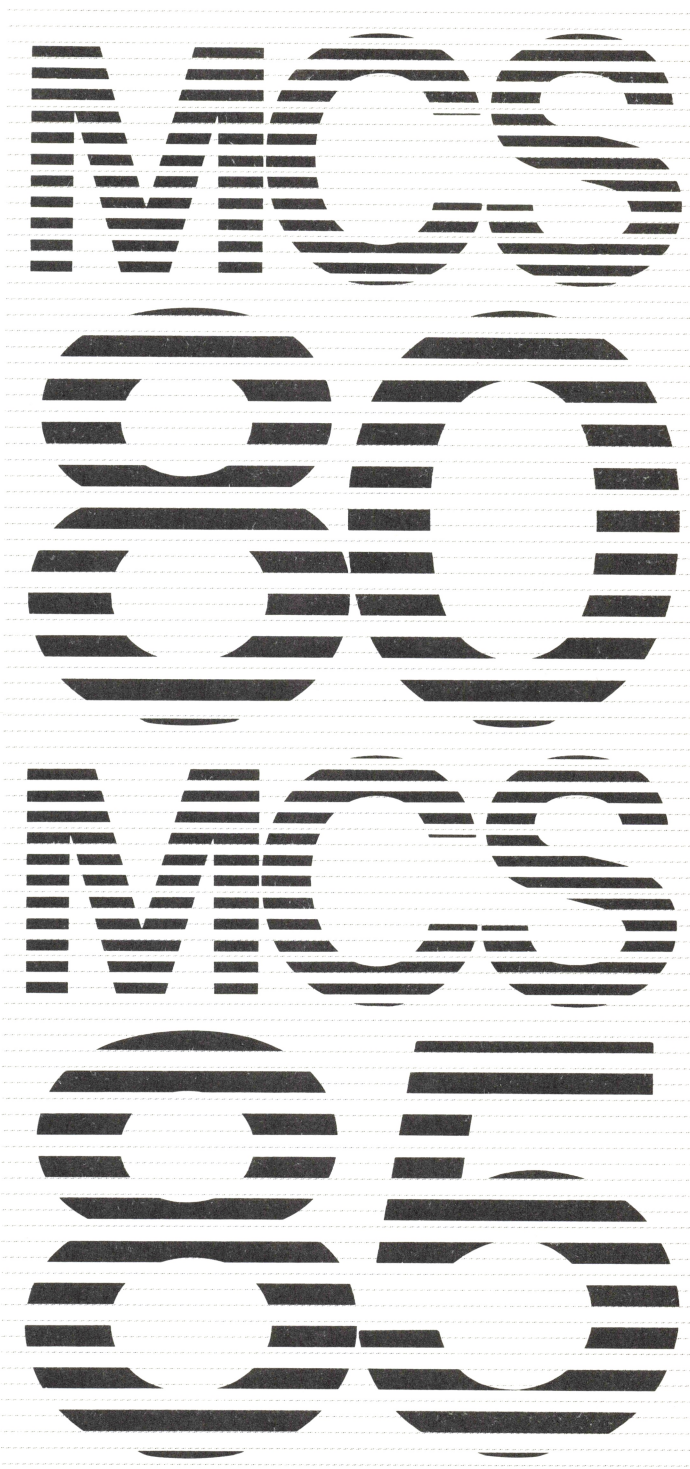
MCS-85™
MCS-80™

Systems
Support
Components

Peripherals

Static RAMs

ROMs-EPROMs



2716
16K (2K x 8) UV ERASABLE PROM

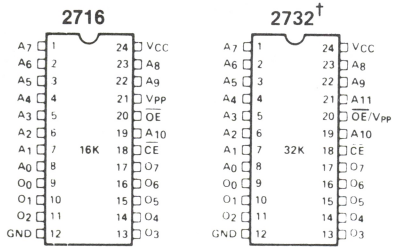
- **Fast Access Time**
  - **— 350 ns Max. 2716-1**
  - **— 390 ns Max. 2716-2**
  - **— 450 ns Max. 2716**
  - **— 650 ns Max. 2716-6**
- **Single +5V Power Supply**
- **Low Power Dissipation**
  - **— 525 mW Max. Active Power**
  - **— 132 mW Max. Standby Power**
- **Pin Compatible to Intel® 2732 EPROM**
- **Simple Programming Requirements**
  - **— Single Location Programming**
  - **— Programs with One 50 ms Pulse**
- **Inputs and Outputs TTL Compatible during Read and Program**
- **Completely Static**

The Intel® 2716 is a 16,384-bit ultraviolet erasable and electrically programmable read-only memory (EPROM). The 2716 operates from a single 5-volt power supply, has a static standby mode, and features fast single address location programming. It makes designing with EPROMs faster, easier and more economical.

The 2716, with its single 5-volt supply and with an access time up to 350 ns, is ideal for use with the newer high performance +5V microprocessors such as Intel's 8085 and 8086. The 2716 is also the first EPROM with a static standby mode which reduces the power dissipation without increasing access time. The maximum active power dissipation is 525 mW while the maximum standby power dissipation is only 132 mW, a 75% savings.

The 2716 has the simplest and fastest method yet devised for programming EPROMs – single pulse TTL level programming. No need for high voltage pulsing because all programming controls are handled by TTL signals. Program any location at any time—either individually, sequentially or at random, with the 2716's single address location programming. Total programming time for all 16,384 bits is only 100 seconds.

PIN CONFIGURATION



†Refer to 2732 data sheet for specifications

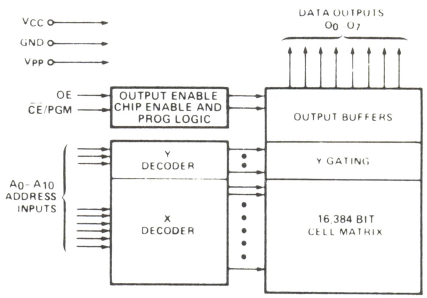
PIN NAMES

A_0–A_{10}	ADDRESSES
$\overline{CE}$/PGM	CHIP ENABLE/PROGRAM
$\overline{OE}$	OUTPUT ENABLE
O_0–O_7	OUTPUTS

MODE SELECTION

MODE \ PINS	$\overline{CE}$/PGM (18)	$\overline{OE}$ (20)	V_{PP} (21)	V_{CC} (24)	OUTPUTS (9-11, 13-17)
Read	V_{IL}	V_{IL}	+5	+5	D_{OUT}
Standby	V_{IH}	Don't Care	+5	+5	High Z
Program	Pulsed V_{IL} to V_{IH}	V_{IH}	+25	+5	D_{IN}
Program Verify	V_{IL}	V_{IL}	+25	+5	D_{OUT}
Program Inhibit	V_{IL}	V_{IH}	+25	+5	High Z

BLOCK DIAGRAM



PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

2732
32K (4K x 8) UV ERASABLE PROM

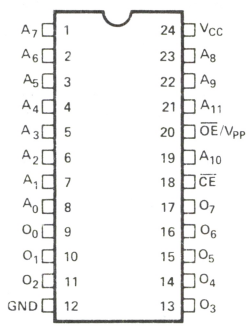
- **Fast Access Time:**
  - **— 450 ns Max. 2732**
  - **— 550 ns Max. 2732-6**
- **Single +5V ± 5% Power Supply**
- **Output Enable for MCS-85™ and MCS-86™ Compatibility**
- **Low Power Dissipation:**
  150mA Max. Active Current
  30mA Max. Standby Current
- **Pin Compatible to Intel® 2716 EPROM**
- **Completely Static**
- **Simple Programming Requirements**
  - **— Single Location Programming**
  - **— Programs with One 50ms Pulse**
- **Three-State Output for Direct Bus Interface**

The Intel® 2732 is a 32,768-bit ultraviolet erasable and electrically programmable read-only memory (EPROM). The 2732 operates from a single 5-volt power supply, has a standby mode, and features an output enable control. The total programming time for all bits is three and a half minutes. All these features make designing with the 2732 in microcomputer systems faster, easier, and more economical.

An important 2732 feature is the separate output control, Output Enable ($\overline{OE}$), from the Chip Enable control ($\overline{CE}$). The $\overline{OE}$ control eliminates bus contention in multiple bus microprocessor systems. Intel's Application Note AP-30 describes the microprocessor system implementation of the $\overline{OE}$ and $\overline{CE}$ controls on Intel's 2716 and 2732 EPROMs. AP-30 is available from Intel's Literature Department.

The 2732 has a standby mode which reduces the power dissipation without increasing access time. The maximum active current is 150mA, while the maximum standby current is only 30mA, an 80% savings. The standby mode is achieved by applying a TTL-high signal to the $\overline{CE}$ input.

PIN CONFIGURATION



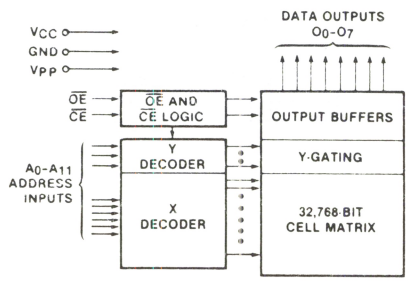
PIN NAMES

A_0-A_{11}	ADDRESSES
$\overline{CE}$	CHIP ENABLE
$\overline{OE}$	OUTPUT ENABLE
O_0-O_7	OUTPUTS

MODE SELECTION

MODE \ PINS	$\overline{CE}$ (18)	$\overline{OE}/V_{PP}$ (20)	V_{CC} (24)	OUTPUTS (9-11,13-17)
Read	V_{IL}	V_{IL}	+5	D_{OUT}
Standby	V_{IH}	Don't Care	+5	High Z
Program	V_{IL}	V_{PP}	+5	D_{IN}
Program Verify	V_{IL}	V_{IL}	+5	D_{OUT}
Program Inhibit	V_{IH}	V_{PP}	+5	High Z

BLOCK DIAGRAM



PRELIMINARY
Notice: This is not a final specification. Some parameter limits are subject to change.

PROGRAMMING

The programming specifications are described in the Data Catalog PROM/ROM Programming Instructions Section.

ABSOLUTE MAXIMUM RATINGS*

Temperature Under Bias ..... -10°C to +80°C
Storage Temperature ..... -65°C to +125°C
All Input or Output Voltages with
Respect to Ground ..... +6V to -0.3V

*COMMENT

Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

D.C. AND OPERATING CHARACTERISTICS

T_A = 0°C to 70°C, V_{CC} = +5V ± 5%

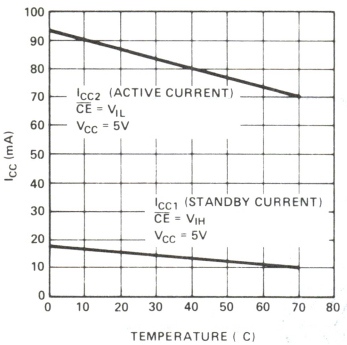
READ OPERATION

Symbol	Parameter	Limits			Unit	Conditions
		Min.	Typ. [1]	Max.		
I_{LI1}	Input Load Current (except $\overline{OE}/V_{PP}$)			10	μA	V_{IN} = 5.25V
I_{LI2}	$\overline{OE}/V_{PP}$ Input Load Current			10	μA	V_{IN} = 5.25V
I_{LO}	Output Leakage Current			10	μA	V_{OUT} = 5.25V
I_{CC1}	V_{CC} Current (Standby)		15	30	mA	$\overline{CE}$ = V_{IH}, $\overline{OE}$ = V_{IL}
I_{CC2}	V_{CC} Current (Active)		85	150	mA	$\overline{OE}$ = $\overline{CE}$ = V_{IL}
V_{IL}	Input Low Voltage	-0.1		0.8	V	
V_{IH}	Input High Voltage	2.0		V_{CC}+1	V	
V_{OL}	Output Low Voltage			0.45	V	I_{OL} = 2.1mA
V_{OH}	Output High Voltage	2.4			V	I_{OH} = -400μA

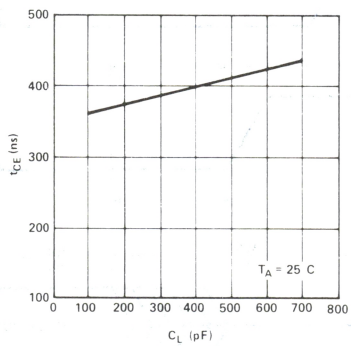
Note: 1. Typical values are for T_A = 25°C and nominal supply voltages.

TYPICAL CHARACTERISTICS

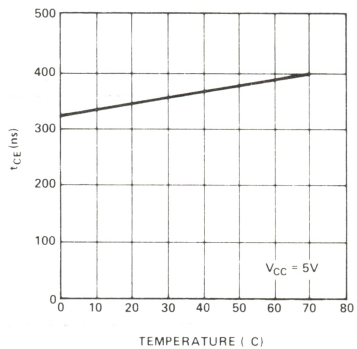
I_{CC} CURRENT VS. TEMPERATURE



$\overline{CE}$ TO OUTPUT DELAY (t_{CE}) VS. CAPACITANCE



$\overline{CE}$ TO OUTPUT DELAY (t_{CE}) VS. TEMPERATURE



PRELIMINARY
Notice: This is not a final specification. Some parametric limits are subject to change.

A.C. CHARACTERISTICS

T_A = 0°C to 70°C, V_{CC} = +5V ± 5%

Symbol	Parameter	2732 Limits		2732-6 Limits		Unit	Test Conditions
		Min.	Max.	Min.	Max.		
t_{ACC}	Address to Output Delay		450		550	ns	$\overline{CE} = \overline{OE} = V_{IL}$
t_{CE}	$\overline{CE}$ to Output Delay		450		550	ns	$\overline{OE} = V_{IL}$
t_{OE}	Output Enable to Output Delay		120		120	ns	$\overline{CE} = V_{IL}$
t_{DF}	Output Enable High to Output Float	0	100	0	100	ns	$\overline{CE} = V_{IL}$
t_{OH}	Output Hold from Addresses, $\overline{CE}$ or $\overline{OE}$, Whichever Occurred First	0		0		ns	$\overline{CE} = \overline{OE} = V_{IL}$

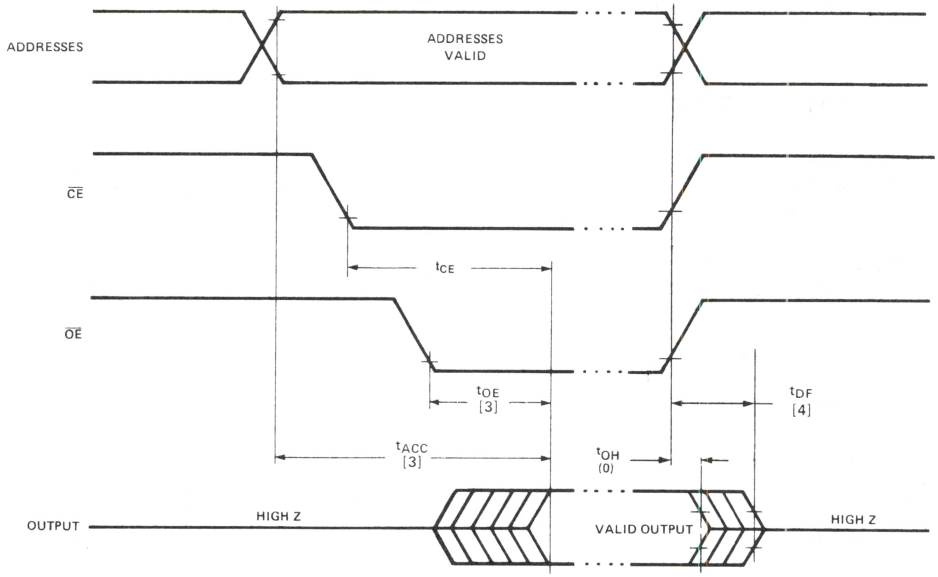
CAPACITANCE [1] T_A = 25°C, f = 1MHz

Symbol	Parameter	Typ.	Max.	Unit	Conditions
C_{IN1}	Input Capacitance Except $\overline{OE}/V_{PP}$	4	6	pF	V_{IN} = 0V
C_{IN2}	$\overline{OE}/V_{PP}$ Input Capacitance		20	pF	V_{IN} = 0V
C_{OUT}	Output Capacitance		12	pF	V_{OUT} = 0V

A.C. TEST CONDITIONS

Output Load: 1 TTL gate and C_L = 100pF
Input Rise and Fall Times: ≤ 20ns
Input Pulse Levels: 0.8V to 2.2V
Timing Measurement Reference Level:
Inputs 1V and 2V
Outputs 0.8V and 2V

A.C. WAVEFORMS [2]



NOTES:
1. THIS PARAMETER IS ONLY SAMPLED AND IS NOT 100% TESTED.
2. ALL TIMES SHOWN IN PARENTHESES ARE MINIMUM TIMES AND ARE NSEC UNLESS OTHERWISE SPECIFIED.
3. $\overline{OE}$ MAY BE DELAYED UP TO 330ns AFTER THE FALLING EDGE OF $\overline{CE}$ WITHOUT IMPACT ON t_{ACC}.
4. t_{DF} IS SPECIFIED FROM $\overline{OE}$ OR $\overline{CE}$, WHICHEVER OCCURS FIRST.

PRELIMINARY
Advance Information
This is not a final specification. Some parametric limits are subject to change.

ERASURE CHARACTERISTICS

The erasure characteristics of the 2732 are such that erasure begins to occur when exposed to light with wavelengths shorter than approximately 4000 Angstroms (Å). It should be noted that sunlight and certain types of fluorescent lamps have wavelengths in the 3000-4000Å range. Data show that constant exposure to room level fluorescent lighting could erase the typical 2732 in approximately 3 years, while it would take approximately 1 week to cause erasure when exposed to direct sunlight. If the 2732 is to be exposed to these types of lighting conditions for extended periods of time, opaque labels are available from Intel which should be placed over the 2732 window to prevent unintentional erasure.

The recommended erasure procedure (see Data Catalog page 4-83) for the 2732 is exposure to shortwave ultraviolet light which has a wavelength of 2537 Angstroms (Å). The integrated dose (i.e., UV intensity X exposure time) for erasure should be a minimum of 15 W-sec/cm^2. The erasure time with this dosage is approximately 15 to 20 minutes using an ultraviolet lamp with a 12000 μW/cm^2 power rating. The 2732 should be placed within 1 inch of the lamp tubes during erasure. Some lamps have a filter on their tubes which should be removed before erasure.

DEVICE OPERATION

The five modes of operation of the 2732 are listed in Table 1. A single 5V power supply is required in the read mode. All inputs are TTL levels except for $\overline{OE}/V_{PP}$ during programming. In the program mode the $\overline{OE}/V_{PP}$ input is pulsed from a TTL level to 25V.

TABLE 1. Mode Selection

MODE \ PINS	$\overline{CE}$ (18)	$\overline{OE}/V_{PP}$ (20)	V_{CC} (24)	OUTPUTS (9-11,13-17)
Read	V_{IL}	V_{IL}	+5	D_{OUT}
Standby	V_{IH}	Don't Care	+5	High Z
Program	V_{IL}	V_{PP}	+5	D_{IN}
Program Verify	V_{IL}	V_{IL}	+5	D_{OUT}
Program Inhibit	V_{IH}	V_{PP}	+5	High Z

Read Mode

The 2732 has two control functions, both of which must be logically satisfied in order to obtain data at the outputs. Chip Enable ($\overline{CE}$) is the power control and should be used for device selection. Output Enable ($\overline{OE}$) is the output control and should be used to gate data to the output pins, independent of device selection. Assuming that addresses are stable, address access time (t_{ACC}) is equal to the delay from $\overline{CE}$ to output (t_{CE}). Data is available at the outputs 120ns (t_{OE}) after the falling edge of $\overline{OE}$, assuming that $\overline{CE}$ has been low and addresses have been stable for at least $t_{ACC} - t_{OE}$.

Standby Mode

The 2732 has a standby mode which reduces the active power current by 80%, from 150mA to 30mA. The 2732 is placed in the standby mode by applying a TTL high signal to the $\overline{CE}$ input. When in standby mode, the outputs are in a high impedance state, independent of the $\overline{OE}$ input.

Output OR-Tieing

Because EPROMs are usually used in larger memory arrays, Intel has provided a 2 line control function that accommodates this use of multiple memory connections. The two line control function allows for:

a) the lowest possible memory power dissipation, and
b) complete assurance that output bus contention will not occur.

To most efficiently use these two control lines, it is recommended that $\overline{CE}$ (pin 18) be decoded and used as the primary device selecting function, while $\overline{OE}$ (pin 20) be made a common connection to all devices in the array and connected to the READ line from the system control bus. This assures that all deselected memory devices are in their low power standby mode and that the output pins are only active when data is desired from a particular memory device.

Programming

Initially, and after each erasure, all bits of the 2732 are in the "1" state. Data is introduced by selectively programming "0's" into the desired bit locations. Although only "0's" will be programmed, both "1's" and "0's" can be presented in the data word. The only way to change a "0" to a "1" is by ultraviolet light erasure.

The 2732 is in the programming mode when the $\overline{OE}/V_{PP}$ input is at 25V. It is required that a 0.1μF capacitor be placed across $\overline{OE}/V_{PP}$ and ground to suppress spurious voltage transients which may damage the device. The data to be programmed is applied 8 bits in parallel to the data output pins. The levels required for the address and data inputs are TTL.

When the address and data are stable, a 50msec, active low, TTL program pulse is applied to the $\overline{CE}$ input. A program pulse must be applied at each address location to be programmed. You can program any location at any time — either individually, sequentially, or at random. The program pulse has a maximum width of 55msec. The 2732 must not be programmed with a DC signal applied to the $\overline{CE}$ input.

Programming of multiple 2732s in parallel with the same data can be easily accomplished due to the simplicity of the programming requirements. Like inputs of the paralleled 2732s may be connected together when they are programmed with the same data. A low level TTL pulse applied to the $\overline{CE}$ input programs the paralleled 2732s.

Program Inhibit

Programming of multiple 2732s in parallel with different data is also easily accomplished. Except for $\overline{CE}$, all like inputs (including $\overline{OE}$) of the parallel 2732s may be common. A TTL level program pulse applied to a 2732's $\overline{CE}$ input with $\overline{OE}/V_{PP}$ at 25V will program that 2732. A high level $\overline{CE}$ input inhibits the other 2732s from being programmed.

Program Verify

A verify should be performed on the programmed bits to determine that they were correctly programmed. The verify is accomplished with $\overline{OE}/V_{PP}$ and $\overline{CE}$ at V_{IL}. Data should be verified t_{DV} after the falling edge of $\overline{CE}$.

2758
8K (1K x 8) UV ERASABLE LOW POWER PROM

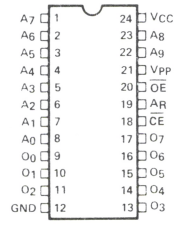
- **Single +5V Power Supply**
- **Simple Programming Requirements**
  - **Single Location Programming**
  - **Programs with One 50 ms Pulse**
- **Low Power Dissipation**
  525 mW Max. Active Power
  132 mW Max. Standby Power
- **Fast Access Time: 450 ns Max. in Active and Standby Power Modes**
- **Inputs and Outputs TTL Compatible during Read and Program**
- **Completely Static**
- **Three-State Outputs for OR-Ties**

The Intel® 2758 is a 8192-bit ultraviolet erasable and electrically programmable read-only memory (EPROM). The 2758 operates from a single 5-volt power supply, has a static standby mode, and features fast single address location programming. It makes designing with EPROMs faster, easier and more economical. The total programming time for all 8192 bits is 50 seconds.

The 2758 has a static standby mode which reduces the power dissipation without increasing access time. The maximum active power dissipation is 525 mW, while the maximum standby power dissipation is only 132 mW, a 75% savings. Power-down is achieved by applying a TTL-high signal to the $\overline{CE}$ input.

A 2758 system may be designed for total upwards compatibility with Intel's 16K 2716 EPROM (see Applications Note 30). The 2758 maintains the simplest and fastest method yet devised for programming EPROMs — single pulse TTL-level programming. There is no need for high voltage pulsing because all programming controls are handled by TTL signals. Program any location at any time — either individually, sequentially, or at random, with the single address location programming.

PIN CONFIGURATION



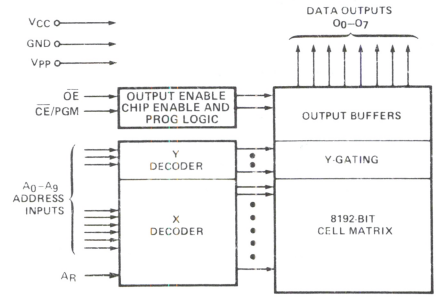
MODE SELECTION

MODE \ PINS	$\overline{CE}$/PGM (18)	A_R (19)	$\overline{OE}$ (20)	V_{PP} (21)	V_{CC} (24)	OUTPUTS (9-11, 13-17)
Read	V_{IL}	V_{IL}	V_{IL}	+5	+5	D_{OUT}
Standby	V_{IH}	V_{IL}	Don't Care	+5	+5	High Z
Program	Pulsed V_{IL} to V_{IH}	V_{IL}	V_{IH}	+25	+5	D_{IN}
Program Verify	V_{IL}	V_{IL}	V_{IL}	+25	+5	D_{OUT}
Program Inhibit	V_{IL}	V_{IL}	V_{IH}	+25	+5	High Z

PIN NAMES

A_0–A_9	ADDRESSES
$\overline{CE}$/PGM	CHIP ENABLE/PROGRAM
$\overline{OE}$	OUTPUT ENABLE
O_0–O_7	OUTPUTS
A_R	SELECT REFERENCE INPUT LEVEL

BLOCK DIAGRAM



3604A, 3624A FAMILY
4K (512 x 8) HIGH-SPEED PROM

	3604A-2 3624A-2	3604A 3624A	3604AL
Max. T_A(ns)	60	70	90
Max. I_{CC}(mA)	170	170	130/25*

*Standby Current When The Chip is Deselected.

- **Fast Access Time --60ns Max (3604A-2, 3624A-2)**
- **Low Standby Power Dissipation (3604AL) --32 μW/Bit Max**
- **Open Collector (3604A) or Three State (3624A) Outputs**
- **Four Chip Select Inputs For Easy Memory Expansion**
- **Polycrystalline Silicon Fuse For Higher Reliability**
- **Hermetic 24 Pin DIP**

The Intel® 3604A/3624A are 4096-bit bipolar PROMs organized as 512 words by 8 bits. The fast second generation 3604A/3624A replaces its Intel predecessor, the 3604/3624. Higher speed PROMs, the 3604A-2/3624A-2, are now available at 60 ns. All 3604A/3624A specifications, except programming, are the same as or better than the 3604/3624. Once programmed, the 3604A/3624A are interchangeable with the 3604/3624

The PROMs are manufactured with all outputs initially logically high. Logic low levels can be electrically programmed in selected bit locations. Both open collector and three-state outputs are available. Low standby power dissipation can be achieved with the 3604AL. The standby power dissipation is approximately 20% of the active power dissipation.

The 3604A/3624A are available in a hermetic 24-pin dual in-line package. These PROMs are manufactured with the time-proven polycrystalline silicon fuse technology.

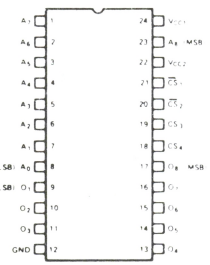
Mode/Pin Connection		Pin 22	Pin 24
READ:	3604A, 3604A-2 3624A, 3624A-2	No Connect or 5V	5V
	3604AL	+5V	Must be Left Open
PROGRAM:	3604A, 3604A-2 3624A, 3624A-2	Pulsed 12.5V	Pulsed 12.5V
	3604AL	Pulsed 12.5V	Pulsed 12.5V
STANDBY:	3604AL	Power dissipation is automatically reduced whenever the 3604AL is deselected.	

PIN NAMES

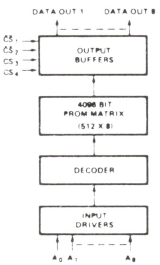
A_0–A_8	ADDRESS INPUTS
$\overline{CS}_1$–$\overline{CS}_2$, CS_3–CS_4 [1]	CHIP SELECT INPUTS
O_1–O_8	DATA OUTPUTS

[1] To select the PROM $\overline{CS}_1 = \overline{CS}_2 = 0$ and $CS_3 = CS_4 = 1$.

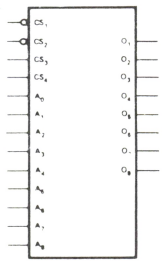
PIN CONFIGURATION



BLOCK DIAGRAM



LOGIC SYMBOL



3605A, 3625A
4K (1K x 4) PROM

3605A-1, 3625A-1	50 ns Max.
3605A, 3625A	60 ns Max.

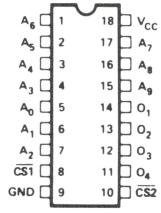
- ± 10% Power Supply Tolerance
- Fast Access Time: 40 ns Typically
- Lower Power Dissipation: 0.14 mW/Bit Typically
- Simple Memory Expansion Two Chip Select Inputs
- Open Collector (3605A) and Three-State (3625A) Outputs
- Polycrystalline Silicon Fuse for Higher Reliability
- Hermetic 18-Pin DIP

The Intel® 3605A and 3625A families are high density, 4096-bit bipolar PROMs organized as 1024 words by 4 bits. The 1024 by 4 organization gives ideal word or bit modularity for memory array expansion. The 3605A has open collector outputs and the 3625A has three-state outputs. The 3605A and 3625A are fully specified over the 0°C to 75°C temperature range with ± 10% power supply variation. Maximum access times of 50 ns (3605A-2/3625A-2) and 60 ns (3605A/3625A) are available at a typical power dissipation of 0.14 mW/bit.

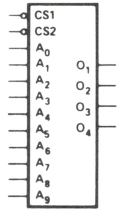
The 3605A/3625A are packaged in an 18-pin dual in-line hermetic package with 300 milli-inch centers. Thus, twice the bit density can be achieved with the 3605A/3625A in the same memory board areas as 512 by 8-bit PROMs in 24-pin packages.

The highly reliable polycrystalline silicon fuse technology is used in the manufacturing of the 3605A and 3625A families. All outputs are initially a logical high and logic low levels can be electrically programmed in selected bit locations.

PIN CONFIGURATION



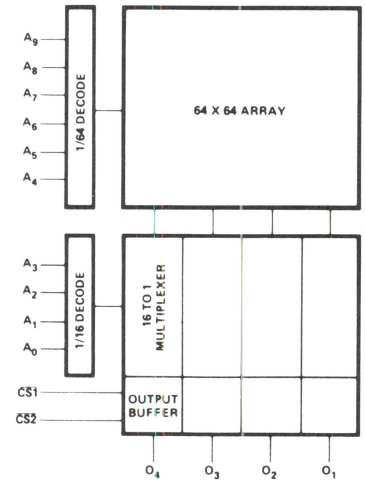
LOGIC SYMBOL



PIN NAMES

A_0 - A_9	ADDRESS INPUTS
$\overline{CS}$	CHIP SELECT INPUT
O_1 - O_4	OUTPUTS

BLOCK DIAGRAM



A. C. Characteristics V_{CC} = +5V ±10%, T_A = 0°C to +75°C

Symbol	Parameter	Max. Limits 3605A-1 3625A-1	Max. Limits 3605A 3625A	Unit	Conditions
t_{A++}, t_{A--} t_{A+-}, t_{A-+}	Address to Output Delay	50	60	ns	$\overline{CS}_1 = \overline{CS}_2 = V_{IL}$ to select the PROM.
t_{S++}	Chip Select to Output Delay	30	30	ns	
t_{S--}	Chip Select to Output Delay	30	30	ns	

Capacitance [1] T_A = 25°C, f = 1 MHz

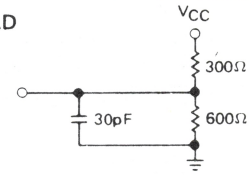
SYMBOL	PARAMETER	LIMITS TYP.	LIMITS MAX.	UNIT	TEST CONDITIONS
C_{INA}	Address Input Capacitance	3	8	pF	V_{CC} = 5V V_{IN} = 2.5V
C_{INS}	Chip-Select Input Capacitance	4	8	pF	V_{CC} = 5V V_{IN} = 2.5V
C_{OUT}	Output Capacitance	5	10	pF	V_{CC} = 5V V_{OUT} = 2.5V

NOTE 1: This parameter is only periodically sampled and is not 100% tested.

Switching Characteristics

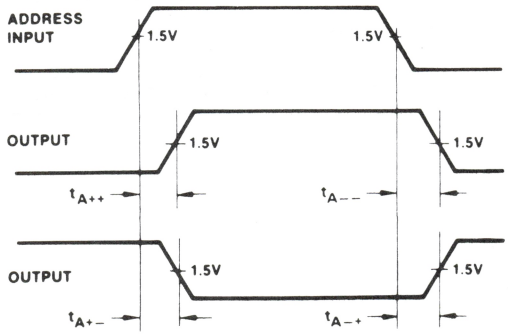
Conditions of Test:
Input pulse amplitudes - 2.5V
Input pulse rise and fall times of
5 nanoseconds between 1 volt and 2 volts
Speed measurements are made at 1.5 volt levels
Output loading is 15 mA and 30 pF
Frequency of test - 2.5 MHz

15mA TEST LOAD

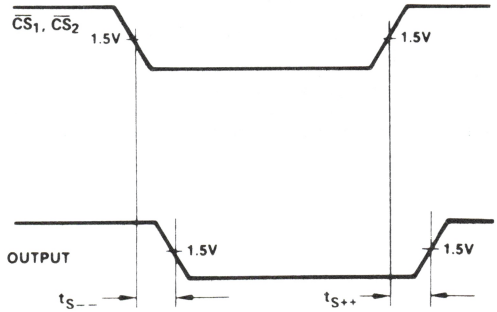


Waveforms

ADDRESS TO OUTPUT DELAY



CHIP SELECT TO OUTPUT DELAY



PROGRAMMING

The programming specifications are described in the Data Catalog PROM/ROM Programming Instructions on page 4-89.

Absolute Maximum Ratings*

Temperature Under Bias . . . . . -65°C to +125°C
Storage Temperature . . . . . -65°C to +160°C
Output or Supply Voltages . . . . . -0.5V to 7 Volts
All Input Voltages . . . . . -1V to 5.5V
Output Currents 100mA

*COMMENT

Stresses above those listed under "Absolute Maximum Rating" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or at any other condition above those indicated in the operational sections of this specification is not implied.

D. C. Characteristics: All Limits Apply for V_{CC} = +5.0V ±10%, T_A = 0°C to +75°C

Symbol	Parameter	Limits				Test Conditions
		Min.	Typ.[1]	Max.	Unit	
I_{FA}	Address Input Load Current		-0.05	-0.25	mA	V_{CC}=5.5V, V_A=0.45V
I_{FS}	Chip Select Input Load Current		-0.05	-0.25	mA	V_{CC}=5.5V, V_S=0.45V
I_{RA}	Address Input Leakage Current			40	μA	V_{CC}=5.5V, V_A = 5.5V
I_{RS}	Chip Select Input Leakage Current			40	μA	V_{CC}=5.5V, V_S = 5.5V
V_{CA}	Address Input Clamp Voltage		-0.9	-1.5	V	V_{CC}=4.5V, I_A=-10mA
V_{CS}	Chip Select Input Clamp Voltage		-0.9	-1.5	V	V_{CC}=4.5V, I_S=-10mA
V_{OL}	Output Low Voltage		0.3	0.45	V	V_{CC}=4.5V, I_{OL}=15mA
I_{CEX}	3605A Output Leakage Current			40	μA	V_{CC}=5.5V, V_{CE}=5.5V
I_{CC}	Power Supply Current		110	140	mA	V_{CC}=5.5V, V_{AO}→V_{A9}=0V, $\overline{CS}_1$=$\overline{CS}_2$=V_{IH}
V_{IL}	Input "Low" Voltage			0.85	V	
V_{IH}	Input "High" Voltage	2.0			V	

3625, 3625-2 ONLY

Symbol	Parameter	Min.	Typ.[1]	Max.	Unit	Test Conditions
$\|I_O\|$	Output Leakage for High Impedance Stage			40	μA	V_O=5.5V or 0.45V, V_{CC}=5.5V, $\overline{CS}_1$=$\overline{CS}_2$=2.4V
I_{SC}[1]	Output Short Circuit Current	-20	-35	-80	mA	V_O = 0V
V_{OH}	Output High Voltage	2.4			V	I_{OH} = -2.4mA, V_{CC} = 4.5V

NOTES: 1. Unmeasured outputs are open during this test.

3628
8K (1K X 8) BIPOLAR PROM

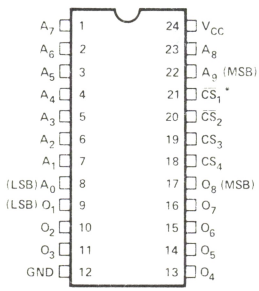
3628	80 ns Max.
3628-4	100 ns Max.

- **Fast Access Time: 65 ns Typically**
- **Low Power Dissipation: 0.09mW/Bit Typically**
- **Four Chip Select Inputs for Easy Memory Expansion**
- **Three-State Outputs**
- **Hermetic 24-Pin DIP**
- **Polycrystalline Silicon Fuses for Higher Fuse Reliability**

The Intel® 3628 is a fully decoded 8192-bit PROM organized as 1024 words by 8 bits. The worst case access time of 80 ns is specified over the 0°C to 75°C temperatue range and 5% V_{CC} power supply tolerances. There are four chip selects provided to facilitate expansion into larger PROM arrays. It uses Schottky clamped TTL technology with poly-crystalline silicon fuses. All outputs are initially high and logic low levels can be electrically programmed in selected bit locations.

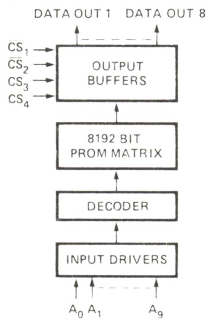
Prior to the 8192 bit 3628, the highest density bipolar PROM available was 4096 bits. The high density of the 3628 now easily doubles the capacity without an increase in area on existing designs currently using 512 words by 8 bit PROMs. There is also little, if any, penalty in power since the 3628 power/bit is approximately one-half that of 4K PROMs. The 3628 is packaged in a hermetic 24-pin dual in-line package.

PIN CONFIGURATION

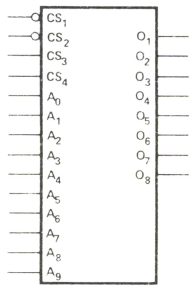


*PROGRAMMING PIN

BLOCK DIAGRAM



LOGIC SYMBOL



PIN NAMES

$A_0 - A_9$	ADDRESS INPUTS
$\overline{CS}_1 - \overline{CS}_2$, $CS_3 - CS_4$	CHIP SELECT INPUTS [1]
$O_1 - O_8$	DATA OUTPUTS

[1] To select the PROM $\overline{CS}_1 = \overline{CS}_2 = V_{IL}$ and $CS_3 = CS_4 = V_{IH}$

PROGRAMMING

The programming specifications are described in the PROM programming section of the Data Catalog.

ABSOLUTE MAXIMUM RATINGS*

Temperature Under Bias . . . . . -65°C to +125°C
Storage Temperature . . . . . -65°C to +160°C
Output or Supply Voltages . . . . . -0.5V to 7 Volts
All Input Voltages . . . . . -1V to 5.5V
Output Currents 100mA

*COMMENT

Stresses above those listed under "Absolute Maximum Rating" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or at any other condition above those indicated in the operational sections of this specification is not implied.

D.C. CHARACTERISTICS: All Limits Apply for $V_{CC} = +5.0V \pm 5\%$, $T_A = 0°C$ to $+75°C$

Symbol	Parameter	Limits				Test Conditions
		Min.	Typ.[1]	Max.	Unit	
I_{FA}	Address Input Load Current		−0.05	−0.25	mA	$V_{CC} = 5.25V$, $V_A = 0.45V$
I_{FS}	Chip Select Input Load Current		−0.05	−0.25	mA	$V_{CC} = 5.25V$, $V_S = 0.45V$
I_{RA}	Address Input Leakage Current			40	μA	$V_{CC} = 5.25V$, $V_A = 5.25V$
I_{RS}	Chip Select Input Leakge Current			40	μA	$V_{CC} = 5.25V$, $V_S = 5.0V$
$\|I_O\|$	Output Leakge for High Impedance State			100	μA	$V_O = 5.25V$ or $0.45V$, $V_{CC} = 5.25V$, $CS_1 = CS_2 = 2.4V$
I_{SC}[2]	Output Short Circuit Current	−20	−35	−80	mA	$V_O = 0V$
V_{CA}	Address Input Clamp Voltage		−0.9	−1.5	V	$V_{CC} = 4.75V$, $I_A = -10mA$
V_{CS}	Chip Select Input Clamp Voltage		−0.9	−1.5	V	$V_{CC} = 4.75V$, $I_S = -10mA$
V_{OL}	Output Low Voltage		0.3	0.45	V	$V_{CC} = 4.75V$, $I_{OL} = 10mA$
V_{OH}	Output High Voltage	2.4	3.4		V	$I_{OH} = -2.4mA$, $V_{CC} = 4.75V$
I_{CC}	Power Supply Current		150	190	mA	$V_{CC} = 5.25V$, $V_{A0} \rightarrow V_{A9} = 0V$, PROM deselected
V_{IL}	Input "Low" Voltage			0.85	V	$V_{CC} = 5.0V$
V_{IH}	Input "High" Voltage	2.0			V	$V_{CC} = 5.0V$

NOTES: 1. Typical values are at 25°C and at nominal voltage.
2. Unmeasured outputs are open during this test.

A.C. CHARACTERISTICS V_{CC} = +5V ±5%, T_A = 0°C to +75°C

SYMBOL	PARAMETER	MAX. LIMITS		UNIT	CONDITIONS
		3628	3628-4		
t_A	Address to Output Delay	80	100	ns	$\overline{CS}_1 = \overline{CS}_2 = V_{IL}$ and $CS_3 = CS_4 = V_{IH}$ to select the PROM.
t_{EN}	Output Enable Time	40	45	ns	
t_{DIS}	Output Disable Time	40	45	ns	

CAPACITANCE[1] T_A = 25°C, f = 1 MHz

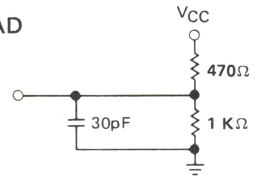
SYMBOL	PARAMETER	TYP. LIMITS		UNIT	TEST CONDITIONS	
		TYP.	MAX.			
C_{INA}	Address Input Capacitance	4	10	pF	V_{CC} = 5V	V_{IN} = 2.5V
C_{INS}	Chip-Select Input Capacitance	6	10	pF	V_{CC} = 5V	V_{IN} = 2.5V
C_{OUT}	Output Capacitance	7	15	pF	V_{CC} = 5V	V_{OUT} = 2.5V

NOTE 1: This parameter is only periodically sampled and is not 100% tested.

SWITCHING CHARACTERISTICS

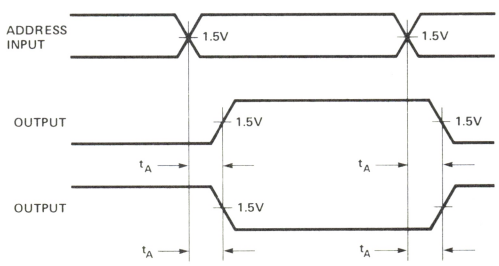
Conditions of Test:
Input pulse amplitudes - 2.5V
Input pulse rise and fall times of
5 nanoseconds between 1 volt and 2 volts
Speed measurements are made at 1.5 volt levels
Output loading is 10 mA and 30 pF
Frequency of test - 2.5 MHz

10 mA TEST LOAD

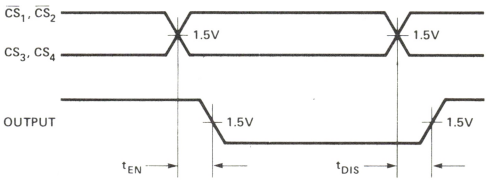


WAVEFORMS

ADDRESS TO OUTPUT DELAY



CHIP SELECT TO OUTPUT DELAY



3636
16K (2K × 8) BIPOLAR PROM

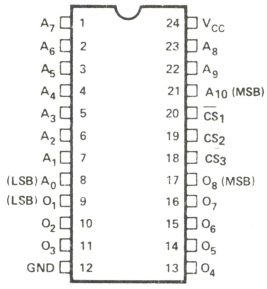
3636-1	65 ns Max.
3636	80 ns Max.

- **Fast Access Time: 50 ns Typically**
- **Low Power Dissipation: 0.05 mW/Bit Typically**
- **Three Chips Select Input for Easy Memory Expansion**
- **Three-State Outputs**
- **Hermetic 24-Pin DIP**
- **Polycrystalline Silicon Fuses for Higher Fuse Reliability**

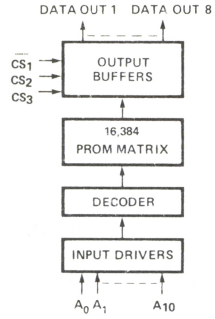
The Intel® 3636 is a fully decoded 16,384 bit PROM organized as 2048 words by 8 bits. The worst case access time of 65 ns is specified over the 0°C to 75°C temperature range and 10% V_{CC} power supply tolerances. There are three chip selects provided to facilitate expansion into larger PROM arrays. The PROMs use the Schottky clamped TTL technology with polycrystalline silicon fuses. All outputs are initially high and logic low levels can be electrically programmed in selected bit locations.

Prior to the 16,384 bit 3636, the highest density bipolar PROM available was 8192 bits. The high density of the 3636 now easily doubles the capacity without an increase in area on existing designs currently using 1024 by 8 bit PROMs. There is also little, if any, penalty in power since the power/bit is approximately one-half that of 8K PROMs. The 3636 is packaged in a hermetic 24-pin dual in-line package.

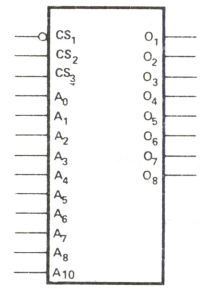
PIN CONFIGURATION



BLOCK DIAGRAM



LOGIC SYMBOL



PIN NAMES

A_0-A_{10}	ADDRESS INPUTS
$\overline{CS}_1$, CS_2, CS_3	CHIP SELECT INPUTS(1)
O_1-O_8	DATA OUTPUTS

(1) To select the PROM $\overline{CS}_1 = V_{IL}$ and $CS_2 = CS_3 = V_{IH}$

PROGRAMMING

The programming specifications are described in the PROM Programming Section of the Data Catalogue.

ABSOLUTE MAXIMUM RATINGS*

Temperature Under Bias . . . . . -65°C to +125°C
Storage Temperature . . . . . -65°C to +160°C
Output or Supply Voltages . . . . . -0.5V to 7 Volts
All Input Voltages . . . . . -1V to 5.5V
Output Currents 100mA

*COMMENT

Stresses above those listed under "Absolute Maximum Rating" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or at any other condition above those indicated in the operational sections of this specification is not implied.

D.C. CHARACTERISTICS: All Limits Apply for $V_{CC} = +5.0V \pm 10\%$, $T_A = 0°C$ to $+75°C$

Symbol	Parameter	Limits				Test Conditions
		Min.	Typ.[1]	Max.	Unit	
I_{FA}	Address Input Load Current		−0.05	−0.25	mA	$V_{CC} = 5.5V$, $V_A = 0.45V$
I_{FS}	Chip Select Input Load Current		−0.05	−0.25	mA	$V_{CC} = 5.5V$, $V_S = 0.45V$
I_{RA}	Address Input Leakage Current			40	μA	$V_{CC} = 5.5V$, $V_A = 5.5V$
I_{RS}	Chip Select Input Leakage Current			40	μA	$V_{CC} = 5.5V$, $V_S = 5.5V$
$\|I_O\|$	Output Leakage for High Impedance State			100	μA	$V_O = 5.5V$ or 0.45V, $V_{CC} = 5.5V$, $CS_1 = 2.4V$
I_{SC}[2]	Output Short Circuit Current	−20	−40	−80	mA	$V_O = 0V$
V_{CA}	Address Input Clamp Voltage		−0.9	−1.5	V	$V_{CC} = 4.5V$, $I_A = -10$ mA
V_{CS}	Chip Select Input Clamp Voltage		−0.9	−1.5	V	$V_{CC} = 4.5V$, $I_S = -10$ mA
V_{OH}	Output High Voltage	2.4	3.2		V	$I_{OH} = -2.4$ mA, $V_{CC} = 4.5V$
V_{OL}	Output Low Voltage		0.3	0.45	V	$V_{CC} = 4.5V$, $I_{OL} = 10$ mA
I_{CC}	Power Supply Current		150	185	mA	$V_{CC} = 5.5V$
V_{IL}	Input "Low" Voltage			0.85	V	$V_{CC} = 5.0V \pm 10\%$
V_{IH}	Input "High" Voltage	2.0			V	$V_{CC} = 5.0V \pm 10\%$

NOTES: 1. Typical values are for $T_A = 25°C$ and nominal supply voltages.
2. Unmeasured outputs are open during this test.

A.C. CHARACTERISTICS $V_{CC} = \pm 5V \pm 10\%$, $T_A = 0°C$ to $+75°C$

SYMBOL	PARAMETER	MAX. LIMITS		UNIT	CONDITIONS
		3636-1	3636		
t_A	Address to Output Delay	65	80	ns	$\overline{CS_1} = V_{IL}$ and $CS_2 = CS_3 = V_{IH}$ to select the PROM.
t_{EN}	Output Enable Time	40	50	ns	
t_{DIS}	Output Disable Time	40	50	ns	

CAPACITANCE [1] $T_A = 25°C$, f = 1 MHz

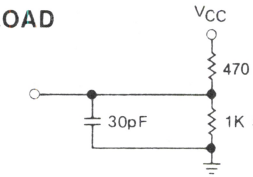
SYMBOL	PARAMETER	TYP. LIMITS		UNIT	TEST CONDITIONS
		TYP.	MAX.		
C_{INA}	Address Input Capacitance	4	10	pF	$V_{CC} = 5V$ $V_{IN} = 2.5V$
C_{INS}	Chip-Select Input Capacitance	6	10	pF	$V_{CC} = 5V$ $V_{IN} = 2.5V$
C_{OUT}	Output Capacitance	7	12	pF	$V_{CC} = 5V$ $V_{OUT} = 2.5V$

NOTE 1: This parameter is only periodically sampled and is not 100% tested.

SWITCHING CHARACTERISTICS

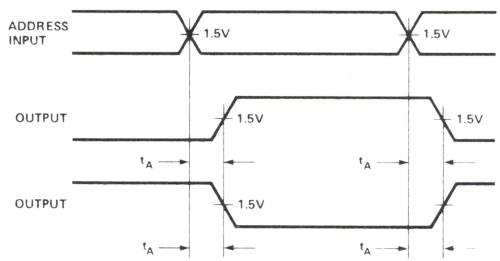
Conditions of Test:
Input pulse amplitudes: 2.5V
Input pulse rise and fall times of
5 nanoseconds between 1 volt and 2 volts
Speed measurements are made at 1.5 volt levels
Output loading is 10 mA and 30 pF
Frequency of test: 2.5 MHz

10 mA TEST LOAD

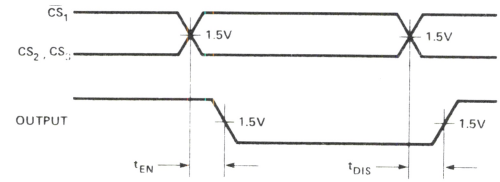


WAVEFORMS

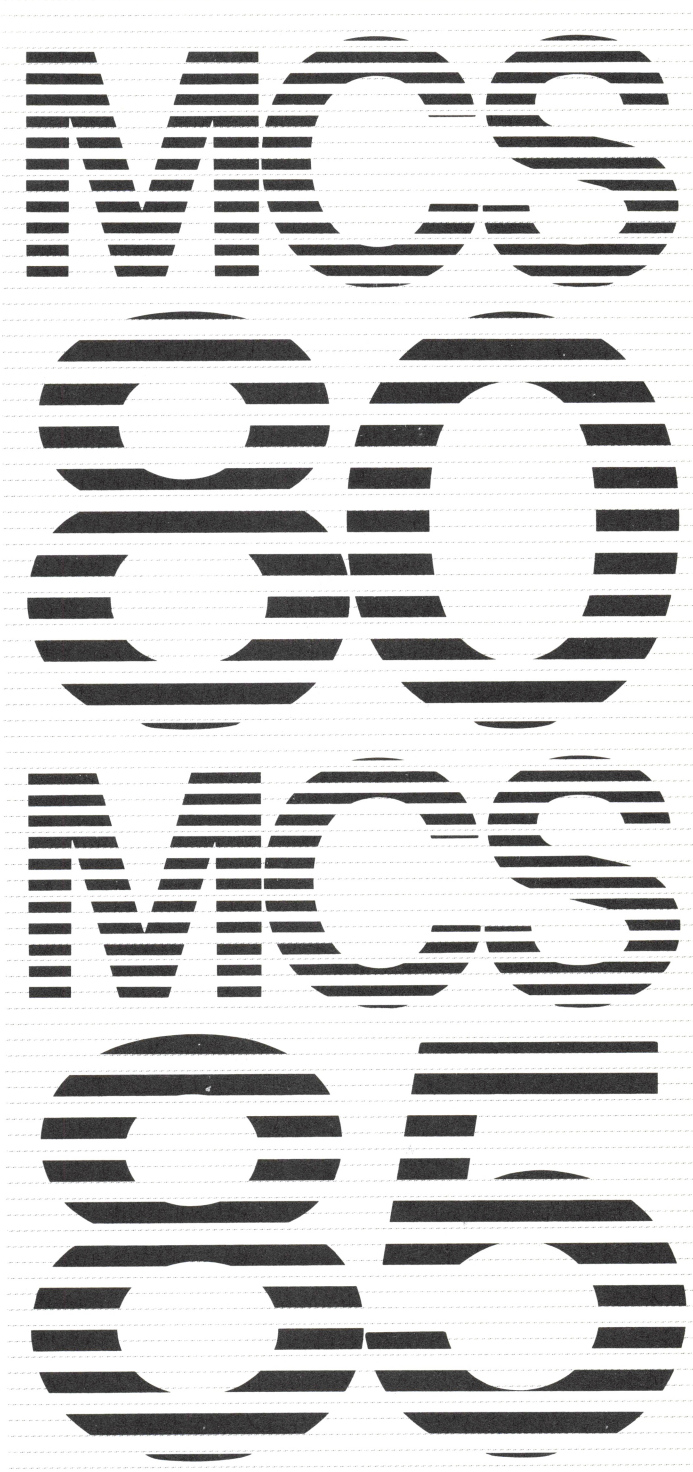
ADDRESS TO OUTPUT DELAY



CHIP SELECT TO OUTPUT DELAY



Chapter 7
Development Aids



ICE-80™
8080 IN-CIRCUIT EMULATOR

Connects Intellec® system to user configured system via an external cable and 40-pin plug, replacing the user system 8080

Allows real-time (2 MHz) emulation of user system 8080

Shares Intellec® RAM, ROM, and PROM memory and Intellec® I/O facilities with user system

Checks for up to three hardware and four software break conditions

Offers full symbolic debugging capabilities

Eliminates need for extraneous debugging tools residing in user system

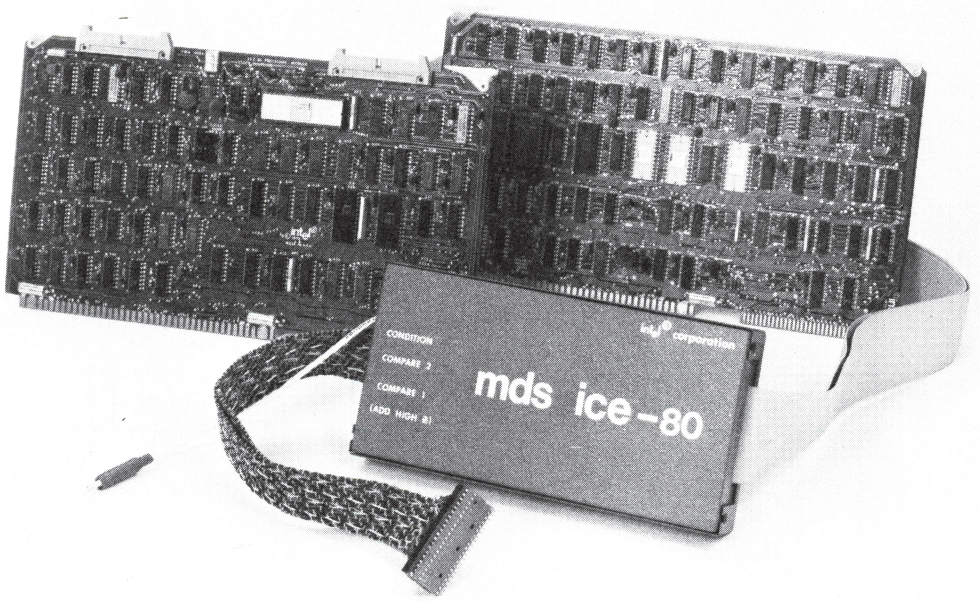
Provides address, data, and 8080 status information on last 44 machine cycles emulated

Provides capability to examine and alter CPU registers, main memory, pin, and flag values

Integrates hardware and software development efforts

Available in diskette or paper tape versions

The Intellec ICE-80 8080 In-Circuit Emulator is an Intellec resident module designed to interface with any user configured 8080 system. With ICE-80 as a replacement for a prototype system 8080, the designer may emulate the system's 8080 in real time, single step the system's program, and substitute Intellec memory and I/O for user system equivalents. Powerful Intellec debug functions are extended into the user system. For the first time the designer may examine and modify his system with symbolic references instead of absolute values.



FUNCTIONAL DESCRIPTION

Integrated Hardware/Software Development

Use of the ICE-80 module enables the system integration phase, which can be so costly and frustrating when attempting to mesh completed hardware and software products, to become a convenient two-way debug tool when begun early in the design cycle. The user prototype need consist of no more than an 8080 CPU socket and a user bus to begin integration of software and hardware development efforts. With the ICE-80 mapping capabilities, system resources may be accessed for missing prototype hardware. Hardware designs may be tested using system software to drive the final product. A functional block diagram of the ICE-80 module is shown in Figure 7-1.

Symbolic Debugging Capability

ICE-80 provides for user-defined symbolic references to program memory addresses and data. Symbols may be substituted for numeric values in any of the ICE-80 commands. The user is thus relieved from looking up addresses of variables or program subroutines.

Symbol Table — The user symbol table generated along with the object file during a PL/M-80 compilation or a MAC80 or resident assembly, is loaded to memory along with the user program to be emulated. The user may add to this symbol table any additional symbolic values for memory addresses, constants, or variables found useful during system debugging. By referring to symbolic memory addresses, the user may be assured of examining, changing, or breaking at the intended location.

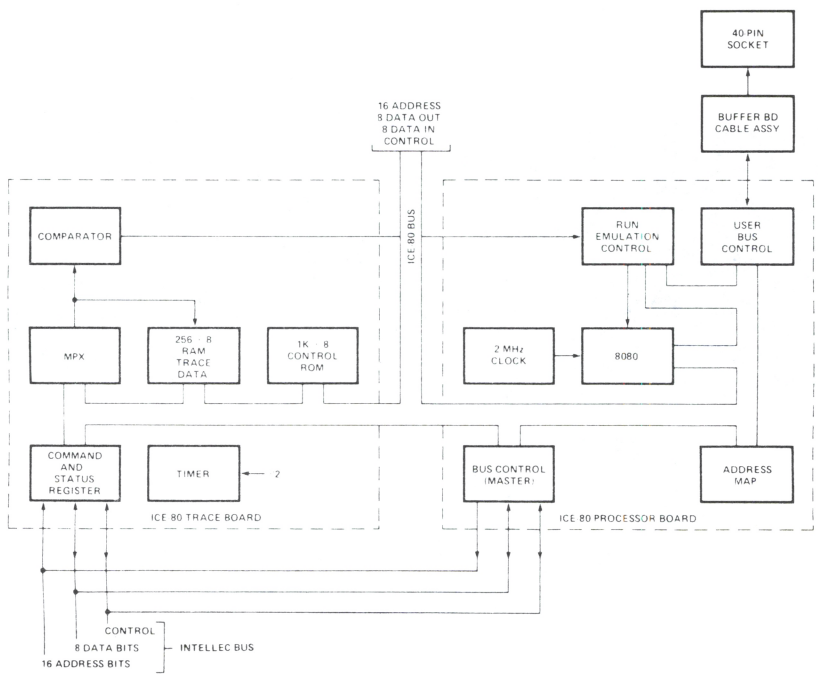
Symbolic Reference — ICE-80 provides symbolic definition of all 8080 registers, flags, and selected pins. The following symbolic references are also provided for user convenience: TIMER, a 16-bit register containing the number of ϕ_2 clock pulses elapsed during emulation; ADDRESS, the address of the last instruction emulated; INTERRUPTENABLED, the user 8080 interrupt mechanism status; and UPPERLIMIT, the highest RAM address occupied by user memory.

Debug Capability Inside User System

ICE-80 provides for user debugging of full prototype or production systems without introducing extraneous hardware or software test tools. ICE-80 connects to the user system through the socket provided for the user 8080 in the user system (see Figure 7-2). Intellec memory is used for the execution of the ICE-80 software, while I/O provides the user with the ability to communicate with ICE-80 and receive information on the generation of the user system. A sample ICE-80 debug session is shown in Figure 7-3.

I/O Mapping and Memory

Memory and I/O for the user system may be resident in the user system or "borrowed" from the Intellec system through ICE-80's mapping capability.



7-1. Functional Block Diagram of ICE-80 Module

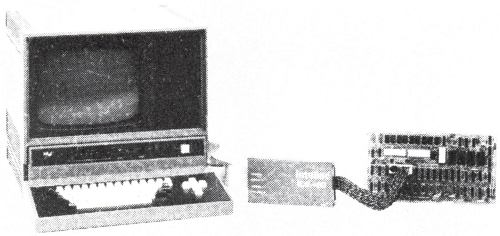


Figure 7-2. ICE-80 Module Installed in User System

Memory Blocking — ICE-80 separates user memory into 16 4K blocks. User I/O is divided into 16 16-port blocks. Each block of memory or I/O may be defined independently. The user may assign system equivalents to take the place of devices not yet designed for the user system during prototyping. In addition, memory or I/O may be accessed in place of user system devices during prototype or production checkout.

Error Messages — The user may also designate a block of memory or I/O as nonexistent. ICE-80 issues error messages when memory or I/O designated as nonexisting is accessed by the user program.

Real-Time Trace

ICE-80 captures valuable trace information while the user is executing programs in real time. The 8080 status, the user memory or port addressed, and the data read or written (snap data), is stored for the last 44 machine cycles executed. This provides ample data for determining how the user system was reacting prior to emulation break. It is available whether the break was user initiated or the result of an error condition. For detailed information on the actions of CPU registers, flags, or other system operations, the user may operate in single or multiple step sequences tailored to system debug needs.

Hardware

The heart of the ICE-80 is a microcomputer system utilizing Intel's 8080 microprocessor as its nucleus. This system communicates with the Intellec host processor via I/O commands. Host processor commands and ICE-80 status are interchanged through registers on the ICE-80 trace board. ICE-80 and the system also communicate through a control block resident in the Intellec main memory, which contains detailed configuration and status information transmitted at an emulation break. ICE-80 hardware consists of two PC boards — the processor and trace boards residing in the Intellec chassis — and a 6-foot cable interfacing to the user system. The trace and processor boards communicate with the system on the bus, and also with each other on a separate ICE-80 bus. ICE-80 connects to the user system through a cable that plugs directly into the socket provided for the user's 8080.

Trace Board

The trace board talks to the system as a peripheral device. It receives commands to ICE-80 and returns ICE-80 responses. While ICE-80 is executing the user program, the trace board collects data for each machine cycle emulated (snap data). The information is continuously stored in high-speed bipolar memory.

Breakpoint — The trace board also contains two 24-bit hardware breakpoint registers which can be loaded by the user. While in emulation mode, a hardware comparitor is constantly monitoring address and status lines for a match to terminate an emulation. A user probe is also available for attachment to any user signal. When this signal goes true a break condition is recognized.

Interrogation — The trace board signals the processor board when a command to ICE-80 or break condition has been detected. The ICE-80 CPU then sends data stored on the trace board to the control block in memory. Snap data, along with information on 8080 registers and pin status and the reason for the emulation break, are then available for access during interrogation mode. Error conditions, if present, are transmitted and automatically displayed for the user.

Processor Board

An 8080 CPU resides on the processor board. During emulation it executes instructions from the user's program. At all other times it executes instructions from the control program in the trace module's ROM.

Timing — The processor board contains an internal clock generator to provide clocks to the user emulation CPU at 2 MHz. The CPU can alternately be driven by a clock derived from user system signal lines. The clock source is selected by a jumper option on the board. A timer on the trace board counts the ϕ_2 clock pulses during emulation and can provide the user with the exact timing of the emulation.

On/Off Control — The processor board turns on an emulation when ICE-80 has received a run command from the system. It terminates emulation when a break condition is detected on the trace board, or the user's program attempts to access memory or I/O ports designated as nonexistent in the user system, or the user 8080 is inactive for a quarter of a second.

Status Storage — The address map located on the processor board stores the assigned location of each user memory or I/O block. During emulation the processor board determines whether to send/receive information

```
ISIS 8080 MACROASSEMBLER, V1.0                PAGE 1

                ;USER PROGRAM TO OUTPUT A SERIES OF
                ;CHARACTERS TO SDK-80 CONSOLE DEVICE
                ;
1320                    ORG     1320H
01E3            C0      EQU     1E3H    ;SDK-80 CONSOLE OUT DRIVER
                ;
1320 0601       START:  MVI     B,1     ;SET UP B VALUE
1322 3A3613             LDA     DAT1    ;LOAD A WITH DAT1 VALUE
135 4F          LOOP:   MDV     C,A
1326 CDE301             CALL    C0      ;SEND C VALUE TO CONSOLE
1329 79                 MOV     A,C     ;RESTORE A
132A 93                 SBB     B       ;SUBTRACT B FROM A
132B 323713             STA     RSLT    ;STORE RESULT IN RSLT
132E FE40               CPI     40H     ;LAST VALUE TO PRINT
1330 C22513             JNZ     LOOP    ;LOOP AGAIN IF A>40H
1333 C32013             JMP     START   ;ELSE RESTART WHOLE PROCEDURE
                ;
1336 5A         DAT1:   DB      5AH
1337            RSLT:   DS      1
0000                    END

ISIS, V1.0      INITIAL ICE-80 SESSION
-ICE80          (Note: The SDK-80 Monitor has already been used to initialize the SDK-80 Board)
ISIS ICE-80, V1.0
(1) **XFORM MEMORY 0 TO 1 U
    *XFORM IO 0FH U
(2) *LOAD PROG. HEX
    ERR = 067
    STAT = 11H TYPE = 06H CMND = 07H ADDR = 1320H GOOD = 06H BAD = 04H
    *CHANGE MEMORY 1321H = FFH
    ERR = 067
    STAT = 11H TYPE = 06H CMND = 07H ADDR = 1321H GOOD = FFH BAD = FDH
    *LOAD PROG. HEX
(3) *GO FROM START UNTIL RSLT WRITTEN
    EMULATION BEGUN
(4) ERR = 067
    STAT = 11H TYPE = 07H CMND = 02H
(5) *DISPLAY CYCLES 5

    STAT = A2H ADDR = 1326H DATA = CDH
    STAT = 82H ADDR = 1327H DATA = E3H
    STAT = 82H ADDR = 1328H DATA = 01H
    STAT = 04H ADDR = FFFFH DATA = 13H
    STAT = 04H ADDR = FFFEH DATA = 29H
(6) *CHANGE DOUBLE REGISTER SP = 13FFH
    *BASE HEX
    *EQUATE STOP = 1333H
(7) *GO FROM START UNTIL STOP EXECUTED THEN DUMP
    EMULATION BEGUN
    B = 01H C = 41H D = 00H E = 00H H = 00H L = 00H F = 56H A = 40H P = 1320H * = 1333H S = 13FFH
    EMULATION TERMINATED AT 1333H
(8) *EXIT
    *FFFF
```

Notes

1. Set up user memory and I/O. The program is set up to execute in block 1 (1000H–1FFFH) of user memory, and requires access to the SDK-80 monitor (block 0) and I/O ports in block 0FH. Both ports and memory are defined as available to the user system. All other memory and I/O is initialized by ICE-80 as nonexistent (guarded).

2. A load command generates an error. The type and command numbers indicate that a data mismatch occurred on a write to memory command. The data to be written to address 1320H should have been 06H. When ICE-80 read the data after writing it, a 04H was detected. A change command to a different memory address hints that bit 1 does not go to 1 anywhere in this memory block. Examination indicates that a pin was shorted on the RAM located at 1300H–13FFH in the prototype system. The problem is fixed and a subsequent load succeeds.

3. A real-time emulation is begun. The program is executed from 'START' (1320H) and continues until 'RSLT' is written [in location 1328H, the contents of the accumulator is stored in (written into) 'RSLT'].

4. An error condition results: TYPE 07, CMND 02 indicate the program accessed is a guarded area.

5. The last 5 machine cycles executed are displayed. The last instruction executed was a call (CDH). The fourth and fifth cycles are a push operation (designated by status 04H) to store the program counter before executing the call. The stack pointer was not initialized in the program and is accessing memory location FFFFH.

6. After making a note to initialize the stack pointer in the next assembly, a temporary fix is effected by setting the stack pointer to the top of user available memory.

7. After setting the base for displays to hex and adding the symbol 'STOP' to the symbol table, emulation is started which will terminate when the instruction at 1333H ('STOP') is executed. When emulation terminates, a dump of the contents of user 8080 registers is requested. One can see that the value of the accumulator is set at 40H, the stack pointer is set at 13FFH, the last address executed (*) is 1333H, and the program counter has been set to 1320H.

8. Exit returns control to the MDS monitor.

Figure 7-3. Sample ICE-80 Debug Session

on the Intellec or user bus by consulting the address map. The processor board allows the ICE-80 CPU to gain access to the bus as a master to "borrow" Intellec facilities. At an emulation break, the processor board stores the status of specified 8080 input and output signals, disables all interaction with the user bus, and commands the trace board to send stored information to a control block in Intellec memory for access during interrogation mode.

Cable Card

The cable card is included for cable driving. It transmits address and data bus information to the user system through a 40-pin connector that plugs into the user system in the socket designed for the 8080 when enabled by the processor module's user bus control logic.

Software

The ICE-80 software driver is a RAM-based program providing easy to use English language commands for defining breakpoints, initiating emulation, and interrogating and altering the user system status recorded during emulation. ICE-80 commands are configured with a broad range of modifiers to provide the user with maximum flexibility in describing the operation to be performed. Listings of emulation commands, interrogation commands, and utility commands are provided in Tables 7-1, 7-2 and 7-3, respectively.

Command	Operation
Go	Initiates real-time emulation and allows user to specify breakpoints, data retrieval, and conditions under which emulation should be reinitiated.
Step	Initiates emulation in single or multiple instruction increments. User may specify register dump or tailor diagnostic activity to his needs following each step, and define conditions under which stepping should continue.
Range	Delimits blocks of instructions for which register dump or tailored diagnostics are to occur.
Continue	Resumes real-time emulation.
Call	Emulates user system interrupt.

Table 7-1. ICE-80 Emulation Commands

Command	Operation
Base	Establishes mode of display for output data.
Display	Prints contents of memory, 8080 registers, input ports, 8080 flags, 8080 pins, snap data, symbol table, or other diagnostic data on list device. May also be used for base-to-base conversion, or for addition or subtraction in any base.
Change	Alters contents of memory, register, output port, or 8080 flag.
XFORM	Defines memory and I/O status.
Search	Looks through memory range for specified value.

Table 7-2. ICE-80 Interrogation Commands

Command	Operation
Load	Fetches user symbol table and object code from input device.
Save	Sends user symbol table and object code to output device.
Equate	Enters symbol name and value to user symbol table.
Fill	Fills memory range with specified value.
Move	Moves block of memory data to another area of memory.
Timeout	Enables/disables user CPU ¼ second wait state timeout.
List	Defines list device (diskette-based version only).
Exit	Returns program control to monitor.

Table 7-3. ICE-80 Utility Commands

SPECIFICATIONS

Paper Tape-Based Operating Environment

Required Hardware
Intellec system
System console
Reader device
Punch device
ICE-80 module

Required Software
System monitor

Diskette-Based Operating Environment

Required Hardware
Intellec system
32K bytes RAM memory
System console
Intellec diskette operating system
ICE-80 module

Required Software
System monitor
ISIS-II

System Clock

Crystal controlled 2.185 MHz ± 0.01%. May be replaced by user clock through jumper selection.

Physical Characteristics

Width — 12.00 in. (30.48 cm)
Height — 6.75 in. (17.15 cm)
Depth — 0.50 in. (1.27 cm)
Weight — 8.00 lb (3.64 kg)

Electrical Characteristics

DC Power Requirements

V_{CC} = + 5V, ± 5%
I_{CC} = 9.81A max; 6.90A typ
V_{DD} = + 12V, ± 5%
I_{DD} = 79 mA max; 45 mA typ
V_{BB} = − 9V, ± 5%
I_{BB} = 1 mA max; 1μA typ

Environmental Characteristics

Operating Temperature — 0°C to 40°C

Operating Humidity — Up to 95% relative humidity without condensation

Equipment Supplied

Printed circuit modules (2)
Interface cables and buffer board
ICE-80 software driver, paper tape version
(ICE-80 software driver, diskette-based version is supplied with diskette operating systems)
Operator's Manual

ORDERING INFORMATION

Part Number	Description
MDS-80-ICE	8080 CPU in-circuit emulator, cable assembly and interactive software included

UPP-103*
UNIVERSAL PROM PROGRAMMER

**Replaces UPP-101, UPP-102 Universal PROM Programmers*

Intellec® development system peripheral for PROM programming and verification

Provides personality cards for programming all Intel PROM families

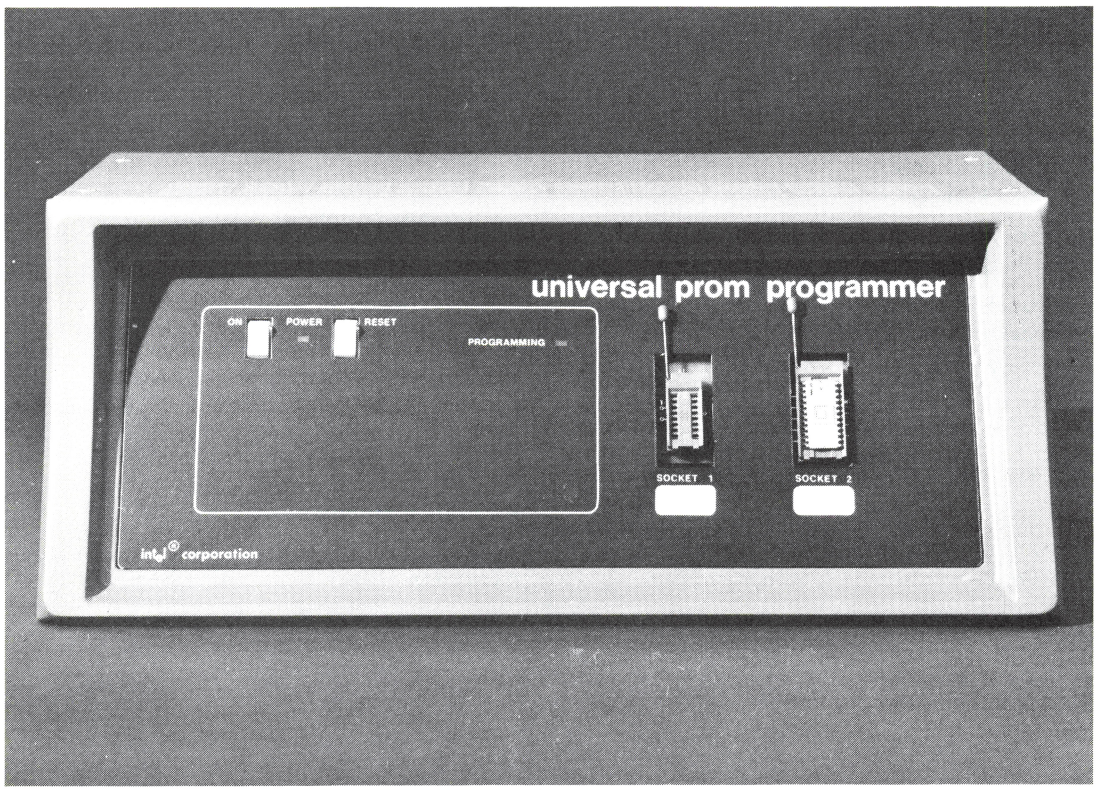
Provides zero insertion force sockets for both 16-pin and 24-pin PROMs

Universal PROM mapper software provides powerful data manipulation and programming commands

Provides flexible power source for system logic and programming pulse generation

Holds two personality cards to facilitate programming operations using several PROM types

The UPP-103 Universal PROM Programmer is an Intellec system peripheral capable of programming and verifying all of the Intel programmable ROMs (PROMs). In addition, the UPP-103 programs the PROM memory portions of the 8748 microcomputer, 8741 UPI, the 8755 PROM and I/O chip and the 2920 signal processor. Programming and verification operations are initiated from the Intellec development system console and are controlled by the universal PROM mapper (UPM) program.



FUNCTIONAL DESCRIPTION

Universal PROM Programmer

The basic Universal PROM Programmer (UPP) consists of a controller module, two personality card sockets, a front panel, power supplies, a chassis, and an Intellec development system interconnection cable. An Intel 4040-based intelligent controller monitors the commands from the Intellec System and controls the data transfer interface between the selected PROM personality card and the Intellec memory. A unique personality card contains the appropriate pulse generation functions for each Intel PROM family. Programming and verifying any Intel PROM may be accomplished by selecting and plugging in the appropriate personality card. The front panel contains a power-on switch and indicator, a reset switch, and two zero-force insertion sockets (one 16-pin and one 24-pin or two 24-pin). A central power supply provides power for system logic and for PROM programming pulse generation. The Universal PROM Programmer may be used as a table top unit or mounted in a standard 19-inch RETMA cabinet.

Universal PROM Mapper

The Universal PROM Mapper (UPM) is the software program used to control data transfer between paper tape or diskette files and a PROM plugged into the Universal PROM Programmer. It uses Intellec system memory for intermediate storage. The UPM transfers data in 8-bit HEX, BNPF, or binary object format between paper tape or diskette files and the Intellec system memory. While the data is in Intellec system memory, it can be displayed and changed. In addition, word length, bit position, and data sense can be adjusted as required for the PROM to be programmed. PROMs may also be duplicated or altered by copying the PROM contents into the Intellec system memory. Easy to use program and compare commands give the user complete control over programming and verification operations. The UPM eliminates the need for a variety of personalized PROM programming routines because it contains the programming algorithms for all Intel PROM families. The UPM (diskette based version) is included with the Universal PROM Programmer.

SPECIFICATIONS

Hardware Interface

Data — Two 8-bit unidirectional buses

Commands — 3 write commands, 2 read commands, one initiate command

Physical Characteristics

Width — 6 in. (14.7 cm)

Height — 7 in. (17.2 cm)

Depth — 17 in. (41.7 cm)

Weight — 18 lb (8.2 kg)

Electrical Characteristics

AC Power Requirements — 50-60 Hz; 115/230V AC: 80W

Environmental Characteristics

Operating Temperature — 0°C to 55°C

Optional Equipment

Personality Cards

UPP-816: 2716 personality card

UPP-832: 2732 personality card

UPP-848: 8748, 8741 personality card with 40-pin adaptor socket

UPP-865: 3602, 3622, 3602A, 3622A, 3621, 3604, 3624, 3604A, 3624A, 3604AL, 36046-6, 3605, 3605A, 3625, 3625A, 3608, 3628, 3636

UPP-872: 8702A/1702A personality card

UPP-878: 8708/8704/2708/2704 personality card

UPP-955: 8755A personality card with 40-pin adaptor socket

PROM Programming Sockets

UPP-501: 16-pin/24-pin socket pair

UPP-502: 24-pin/24-pin socket pair

UPP-562: Socket adaptor for 3621, 3602, 3622, 3602A, 3622A

UPP-555: Socket adaptor for 3604AL, 36046-6, 3608, 3628, 3636

UPP-566: Socket adaptor for 3605, 3625, 3605A, 3625A

Equipment Supplied

Cabinet

Power supplies

4040 intelligent controller module

Specified zero insertion force socket pair

Intellec development system interface cable

Universal PROM Mapper program (diskette-based version)

Reference Manuals

9800819 — Universal PROM Programmer User's Manual (SUPPLIED)

ORDERING INFORMATION

Part Number	Description
UPP-103	Universal PROM programmer with 16-pin/24-pin socket pair and 24-pin/24-pin socket pair.

MODEL 220
INTELLEC® SERIES II
MICROCOMPUTER DEVELOPMENT SYSTEM

Complete microcomputer development system in one package for MCS-86, MCS-85, MCS-80 and MCS-48™ microprocessor families

Single LSI electronics board with CPU, 32K bytes RAM memory, and 4K bytes ROM memory

Self-test diagnostic capability

Eight-level nested, maskable priority interrupt system

Built-in interfaces for high speed paper tape reader/punch, printer, and universal PROM programmer

Integral CRT with detachable upper/ lower case typewriter-style full ASCII keyboard

Integral 250K-byte floppy disk with total storage capacity expandable to over 2M bytes

Powerful ISIS-II Diskette Operating System with relocating macroassembler, linker, and locater

Standard MULTIBUS with multi-processor and DMA capability

Compatible with standard Intellec®/ iSBC™ expansion modules

Software compatible with previous Intellec® systems

The Model 220 Intellec Series II Microcomputer Development System is a complete microcomputer development system integrated into one compact package. It includes a CPU with 32K bytes of RAM memory, 4K bytes of ROM memory, a 2000-character CRT, detachable full ASCII keyboard with cursor controls and upper/lower case capability, and a 250K-byte floppy diskette drive. Powerful ISIS-II Diskette Operating System software allows the Model 220 to be used quickly and efficiently for assembling and debugging programs for Intel's MCS-86, MCS-85, MCS-80, or MCS-48 microprocessor families without the need for paper tape handling. ISIS-II performs all file handling operations for the user, leaving him free to concentrate on the details of his own application. When used in conjunction with an optional in-circuit emulator (ICE) module, the Model 220 provides all the hardware and software development tools necessary for the rapid development of a microcomputer-based product.



FUNCTIONAL DESCRIPTION

Hardware Components

The Intellec Series II Model 220 is a packaged, highly integrated microcomputer development system consisting of a CRT chassis with a 6-slot cardcage, power supply, fans, cables, single floppy diskette drive, and two printed circuit cards. A separate, full ASCII keyboard is connected with a cable.

CPU Cards — The master CPU card contains its own microprocessor, memory, I/O, interrupt, and bus interface circuitry, fashioned from Intel's high-technology LSI components. Known as the integrated processor board (IPB), it occupies the first slot in the cardcage. A second, slave CPU card, is responsible for all remaining I/O control, including the CRT and keyboard interface and floppy disk control. This card, mounted on the rear panel, also contains its own microprocessor, RAM and ROM memory, and I/O interface, thus in effect creating a dual processor environment. Known as the I/O controller (IOC), the slave CPU card communicates with the IPB over an 8-bit bidirectional data bus, thus leaving the remaining 5 slots in the cardcage available for system expansion. A block diagram of the IOC is shown in Figure 7-4.

System Components

The heart of the IPB is an Intel NMOS 8-bit microprocessor, the 8080A-2, running at 2.6 MHz. 32K bytes of RAM memory are provided on the board using Intel 16K RAMs. 4K of ROM is provided, preprogrammed with system bootstrap "self-test" diagnostics and the Intellec Series II System Monitor. The eight-level vectored priority interrupt system allows interrupts to be individually masked. Using Intel's versatile 8259A interrupt controller, the interrupt system may be user programmed to respond to individual needs.

Input/Output

IPB Serial Channels — The I/O subsystem in the Model 220 consists of two parts: the IOC card and two serial channels on the IPB itself. Each serial channel is RS232 compatible and is capable of running asynchronously from 110 to 9600 baud or synchronously from 150 to 56K baud. Both may be connected to a user defined data set or data terminal. One channel contains current loop adapters. Both channels are implemented using Intel's 8251 USART. They can be programmatically selected to perform a variety of I/O functions. Baud rate selection is accomplished programmatically through an Intel 8253 interval timer. The 8253 also serves as a real-time clock for the entire system. I/O activity through both serial channels is signaled to the system through a second 8259 interrupt controller, operating in a polled mode, nested to the primary 8259.

IOC Interface — The remainder of system I/O activity takes place in the IOC. The IOC provides interfaces for the CRT, keyboard, integral floppy disk and standard Intellec peripherals, including a printer, high speed paper tape reader/punch, and universal PROM programmer. The IOC contains its own independent microprocessor, also an 8080A-2. This CPU controls all I/O operations, as well as supervising communications with the IPB. 8K bytes of ROM contain all I/O control firmware. 8K bytes of ROM are used for CRT screen refresh storage and the floppy disk buffer. These do not occupy any space in Intellec Series II main memory since the IOC is a totally independent microcomputer subsystem.

Integral CRT Display — The CRT is a 12-inch raster scan-type monitor with a 50/60 Hz vertical scan rate and 15.5 kHz horizontal scan rate. Controls are provided for brightness and contrast adjustments. The interface to the CRT is provided through an Intel 8275 single chip, programmable CRT controller. The master processor on

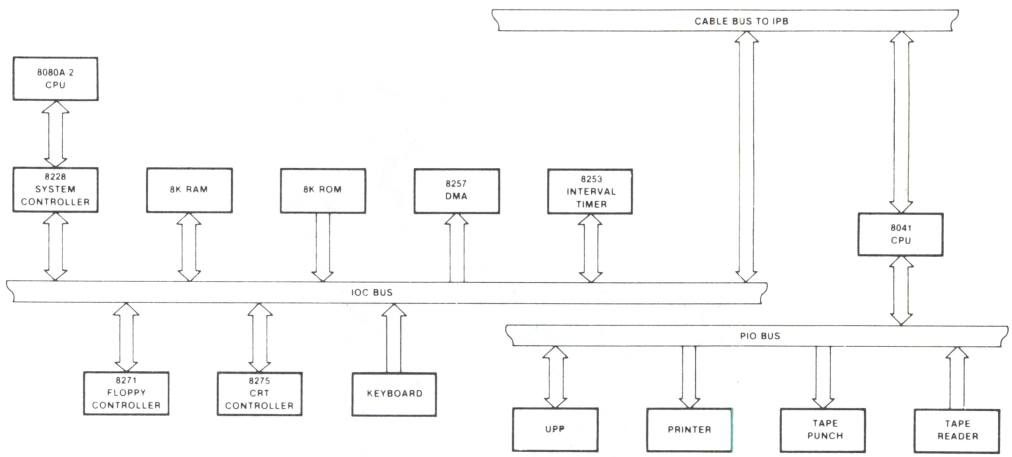


Figure 7-4. I/O Controller (IOC) Block Diagram for the Model 220 Intellec Series II Microcomputer Development System

the IPB transfers a character for display to the IOC, where it is stored in RAM. The CRT controller reads a line at a time into its line buffer through an Intel 8257 DMA controller and then feeds one character at a time to the character generator to produce the video signal. Timing for the CRT control is provided by an Intel 8253 interval timer. The screen display is formatted as 25 rows of 80 characters. The full set of ASCII characters are displayed, including lower-case alphas.

Keyboard — The keyboard interfaces directly to the IOC processor via an 8-bit data bus. The keyboard contains an Intel UPI-41 Universal Peripheral Interface, which scans the keyboard, encodes the characters, and buffers the characters to provide N-key rollover. The keyboard itself is a high quality typewriter-style keyboard containing the full ASCII character set. An upper/lower case switch allows the system to be used for document preparation. Cursor control keys are also provided.

Floppy Disk Drive

The floppy disk drive is controlled by an Intel 8271 single chip, programmable floppy disk controller. It transfers data via an Intel 8257 DMA controller between an IOC RAM buffer and the diskette. The 8271 handles reading and writing of data, formatting diskettes, and reading status, all upon appropriate commands from the IOC microprocessor.

Peripheral Interface

A UPI-41 Universal Peripheral Interface on the IOC board performs similar functions to the UPI-41 on the PIO board in the Model 210. It provides interface for other standard Intellec peripherals, including a printer, high speed paper tape reader, high speed paper tape punch, and universal PROM programmer. Communication between the IPB and IOC is maintained over a separate, 8-bit bidirectional data bus. Connectors for the devices named above, as well as the two serial channels, are mounted directly on the IOC itself.

Control

User control is maintained through a front panel consisting of a power switch and indicator, reset/boot switch, run/halt light, and eight interrupt switches and indicators. The front-panel circuit board is attached directly to the IPB, allowing the eight interrupt switches to connect to the primary 8259A, as well as to the Intellec Series II bus.

MULTIBUS Capability

All Intellec Series II models implement the industry-standard MULTIBUS. MULTIBUS enables several bus masters, such as CPU and DMA devices, to share the bus and memory by operating at different priority levels. Resolution of bus exchanges is synchronized by a bus clock signal derived independently from processor clocks. Read/write transfers may take place at rates up to 5 MHz. The bus structure is suitable for use with any Intel microcomputer family.

Expansion

The Model 220 may be expanded to 64K of RAM and up to 2.25M bytes of on-line diskette storage.

SPECIFICATIONS

Host Processor (IPB)

8080A-2 based, operating at 2.600 MHz.

RAM — 32K, expandable to 64K with iSBC 032 RAM boards (system monitor occupies 62K through 64K)

ROM — 4K (2K in monitor, 2K in boot/diagnostic)

Bus — MULTIBUS, maximum transfer rate of 5 MHz

Clocks — Host processor, crystal controlled at 2.6 MHz, bus clock, crystal controlled at 9.8304 MHz

I/O Interfaces

2 Serial I/O Channels, RS232C, at 110-9600 baud (asynchronous) or 150-56K baud (synchronous). Baud rates and serial format fully programmable using Intel 8251A USARTs. Serial Channel 1 additionally provided with 20 mA current loop. Parallel I/O interfaces provided for paper tape punch, paper tape reader, printer, and UPP-103 Universal PROM Programmer.

Interrupts

8-level, maskable, nested priority interrupt network initiated from front panel or user selected devices.

Direct Memory Access (DMA)

Standard capability on MULTIBUS; implemented for user selected DMA devices through optional DMA module — maximum transfer rate of 2 MHz.

Memory Access Time

RAM — 585 ns max

PROM — 450 ns max

Diskette

Diskette System Capacity — 250K bytes (formatted)

Diskette System Transfer Rate — 160K bits/sec

Diskette System Access Time

Track-to-Track: 10 ms max

Average Random Positioning: 260 ms max

Rotational Speed: 360 rpm

Average Rotational Latency: 83 ms max

Recording Mode: FM

Physical Characteristics

Width — 17.37 in. (44.12 cm)

Height — 15.81 in. (40.16 cm)

Depth — 19.13 in. (48.59 cm)

Weight — 86 lb (39 kg)

Keyboard
Width — 17.37 in. (44.12 cm)
Height — 3.0 in. (7.62 cm)
Depth — 9.0 in. (22.0 cm)
Weight — 6 lb (3 kg)

Electrical Characteristics

DC Power Supply

Volts Supplied	Amps Supplied	Typical System Requirements
+ 5 ± 5%	30.0	7.5
+ 12 ± 5%	2.5	0.2
− 12 ± 5%	0.3	0.05
− 10 ± 5%	1.5	0.15
+ 15 ± 5%	1.5	1.3*
+ 24 ± 5%	1.7	1.2*

*Not available on bus.

AC Requirements
50-60 Hz. 115/230V AC

Equipment Supplied

Model 220 chassis
Integrated processor board (IPB)
I/O controller board (IOC)
CRT and keyboard
250K-byte floppy disk drive
ROM resident system monitor
ISIS-II system diskette with MCS-80/MCS-85 macroassembler

Reference Manuals

9800558 — A Guide to Microcomputer Development Systems (SUPPLIED)

9800559 — Intellec Series II Installation and Service Manual (SUPPLIED)

9800306 — ISIS-II System User's Guide (SUPPLIED)

9800556 — Intellec Series II Hardware Reference Manual (SUPPLIED)

9800555 — Intellec Series II Hardware Interface Manual (SUPPLIED)

9800301 — 8080/8085 Assembly Language Programming Manual (SUPPLIED)

9800605 — Intellec Series II System Monitor Source Listing (SUPPLIED)

9800554 — Intellec Series II Schematic Drawing (SUPPLIED)

Reference manuals are shipped with each product only if designated SUPPLIED (see above). Manuals may be ordered from any Intel sales representative, distributor office or from Intel Literature Department, 3065 Bowers Avenue, Santa Clara, California 95051.

ORDERING INFORMATION

Part Number	Description
MDS-220	Intellec Series II Model 220 microcomputer development system (110V/60 Hz)
MDS-221	Intellec Series II Model 220 microcomputer development system (220V/50 Hz)

MODEL 230
INTELLEC® SERIES II
MICROCOMPUTER DEVELOPMENT SYSTEM

Complete microcomputer development center for Intel MCS-86, MCS-80, MCS-85 and MCS-48™ microprocessor families

LSI electronics board with CPU, RAM, ROM, I/O, and interrupt circuitry

64K bytes RAM memory

Self-test diagnostic capability

Eight-level nested, maskable priority interrupt system

Built-in interfaces for high speed paper tape reader/punch, printer, and universal PROM programmer

Integral CRT with detachable upper/lower case typewriter-style full ASCII keyboard

Powerful ISIS-II Diskette Operating System software with relocating macroassembler, linker, and locater

1 million bytes (expandable to 2.5M bytes) of diskette storage

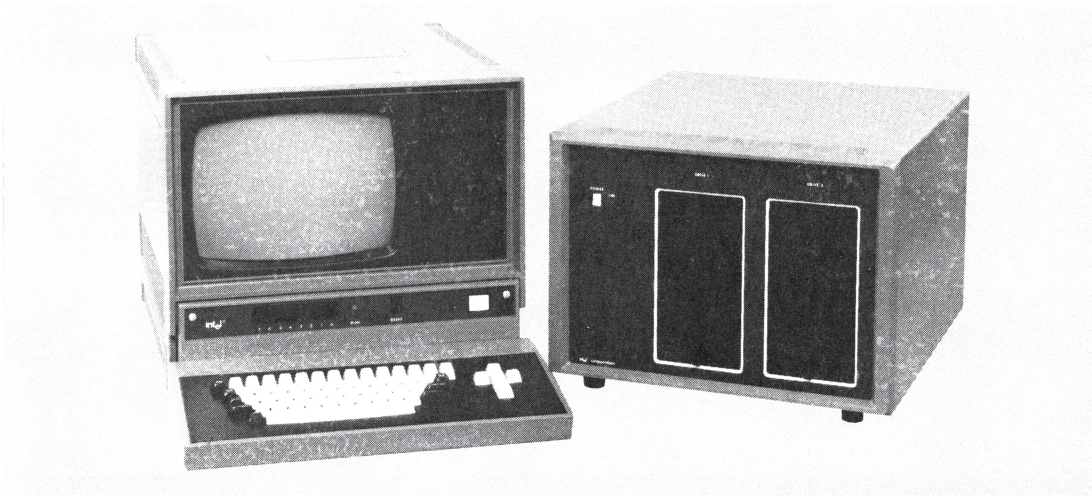
Supports PL/M and FORTRAN high level languages

Standard MULTIBUS with multiprocessor and DMA capability

Compatible with standard Intellec®/iSBC

Software compatible with previous Intellec® systems

The Model 230 Intellec Series II Microcomputer Development System is a complete center for the development of microcomputer-based products. It includes a CPU, 64K bytes of RAM, 4K bytes of ROM memory, a 2000-character CRT, a detachable full ASCII keyboard, and dual double density diskette drives providing over 1 million bytes of on-line data storage. Powerful ISIS-II Diskette Operating System software allows the Model 230 to be used quickly and efficiently for assembling and/or compiling and debugging programs for Intel's MCS-86, MCS-80, MCS-85, or MCS-48 microprocessor families without the need for handling paper tape. ISIS-II performs all file handling operations, leaving the user free to concentrate on the details of his own application. When used in conjunction with an optional in-circuit emulator (ICE) module, the Model 230 provides all the hardware and software development tools necessary for the rapid development of a microcomputer-based product.



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FUNCTIONAL DESCRIPTION

Hardware Components

The Intellec Series II Model 230 is a packaged, highly integrated microcomputer development system consisting of a CRT chassis with a 6-slot cardcage, power supply, fans, cables, and five printed circuit cards. A separate, full ASCII keyboard is connected with a cable. A second chassis contains two floppy disk drives capable of double-density operation along with a separate power supply, fans, and cables for connection to the main chassis. A block diagram of the Model 230 is shown in Figure 7-5.

CPU Cards — The master CPU card contains its own microprocessor, memory, I/O, interrupt and bus interface circuitry fashioned from Intel's high technology LSI components. Known as the integrated processor board (IPB), it occupies the first slot in the cardcage. A second slave CPU card is responsible for all remaining I/O control including the CRT and keyboard interface. This card, mounted on the rear panel, also contains its own microprocessor, RAM and ROM memory, and I/O interface logic, thus, in effect, creating a dual processor environment. Known as the I/O controller (IOC), the slave CPU card communicates with the IPB over an 8-bit bidirectional data bus.

Memory and Control Cards — In addition, 32K bytes of RAM (bringing the total to 64K bytes) is located on a separate card in the main cardcage. Fabricated from Intel's 16K RAMs, the board also contains all necessary address decoding and refresh logic. Two additional boards in the cardcage are used to control the two double-density floppy disk drives.

Expansion — Two remaining slots in the cardcage are available for system expansion. Additional expansion of 4 slots can be achieved through the addition of an Intellec Series II expansion chassis.

System Components

The heart of the IPB is an Intel NMOS 8-bit microprocessor, the 8080A-2, running at 2.6 MHz. 32K bytes of RAM memory are provided on the board using Intel 16K RAMs. 4K of ROM is provided, preprogrammed with system bootstrap "self-test" diagnostics and the Intellec Series II System Monitor. The eight-level vectored priority interrupt system allows interrupts to be individually masked. Using Intel's versatile 8259A interrupt controller, the interrupt system may be user programmed to respond to individual needs.

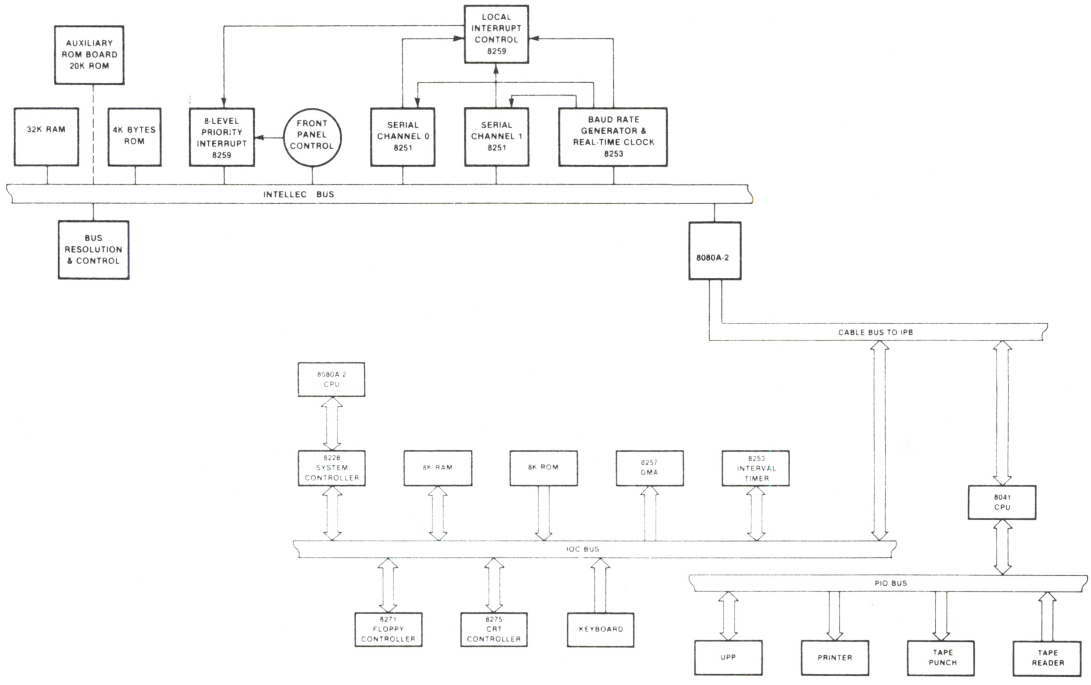


Figure 7-5. Intellec Series II Model 230 Microcomputer Development System Block Diagram

Input/Output

IPB Serial Channels — The I/O subsystem in the Model 230 consists of two parts: the IOC card and two serial channels on the IPB itself. Each serial channel is RS232 compatible and is capable of running asynchronously from 110 to 9600 baud or synchronously from 150 to 56K baud. Both may be connected to a user defined data set or terminal. One channel contains current loop adapters. Both channels are implemented using Intel's 8251A USART. They can be programmatically selected to perform a variety of I/O functions. Baud rate selection is accomplished programmatically through an Intel 8253 interval timer. The 8253 also serves as a real-time clock for the entire system. I/O activity through both serial channels is signaled to the system through a second 8259 interrupt controller, operating in a polled mode nested to the primary 8259.

IOC Interface — The remainder of system I/O activity takes place in the IOC. The IOC provides interface for the CRT, keyboard, and standard Intellec peripherals including printer, high speed paper tape reader/punch, and universal PROM programmer. The IOC contains its own independent microprocessor, also an 8080A-2. The CPU controls all I/O operations as well as supervising communications with the IPB. 8K bytes of ROM contain all I/O control firmware. 8K bytes of RAM are used for CRT screen refresh storage. These do not occupy space in Intellec Series II main memory since the IOC is a totally independent microcomputer subsystem.

Integral CRT

Display — The CRT is a 12-inch raster scan type monitor with a 50/60 Hz vertical scan rate and 15.5 kHz horizontal scan rate. Controls are provided for brightness and contrast adjustments. The interface to the CRT is provided through an Intel 8275 single chip programmable CRT controller. The master processor on the IPB transfers a character for display to the IOC, where it is stored in RAM. The CRT controller reads a line at a time into its line buffer through an Intel 8257 DMA controller and then feeds one character at a time to the character generator to produce the video signal. Timing for the CRT control is provided by an Intel 8253 interval timer. The screen display is formatted as 25 rows of 80 characters. The full set of ASCII characters are displayed, including lower case alphas.

Keyboard — The keyboard interfaces directly to the IOC processor via an 8-bit data bus. The keyboard contains an Intel UPI-41 Universal Peripheral Interface, which scans the keyboard, encodes the characters, and buffers the characters to provide N-key rollover. The keyboard itself is a high quality typewriter style keyboard containing the full ASCII character set. An upper/lower case switch allows the system to be used for document preparation. Cursor control keys are also provided.

Peripheral Interface

A UPI-41 Universal Peripheral Interface on the IOC board performs similar functions to the UPI-41 on the PIO board in the Model 210. It provides interface for other standard Intellec peripherals including a printer, high speed paper tape reader, high speed paper tape punch, and universal PROM programmer. Communication between the IPB and IOC is maintained over a separate 8-bit bidirectional data bus. Connectors for the four devices named above, as well as the two serial channels, are mounted directly on the IOC itself.

Control

User control is maintained through a front panel, consisting of a power switch and indicator, reset/boot switch, run/halt light, and eight interrupt switches and indicators. The front panel circuit board is attached directly to the IPB, allowing the eight interrupt switches to connect to the primary 8259A, as well as to the Intellec Series II bus.

Diskette System

The Intellec Series II double density diskette system provides direct access bulk storage, intelligent controller, and two diskette drives. Each drive provides ½ million bytes of storage with a data transfer rate of 500,000 bits/second. The controller is implemented with Intel's powerful Series 3000 Bipolar Microcomputer Set. The controller provides an interface to the Intellec Series II system bus, as well as supporting up to four diskette drives. The diskette system records all data in soft sector format. The diskette system is capable of performing seven different operations: recalibrate, seek, format track, write data, write deleted data, read data, and verify CRC.

Diskette Controller Boards — The diskette controller consists of two boards, the channel board and the interface board. These two PC boards reside in the Intellec Series II system chassis and constitute the diskette controller. The channel board receives, decodes and responds to channel commands from the 8080A-2 CPU in the Model 230. The interface board provides the diskette controller with a means of communication with the diskette drives and with the Intellec system bus. The interface board validates data during reads using a cyclic redundancy check (CRC) polynomial and generates CRC data during write operations. When the diskette controller requires access to Intellec system memory, the interface board requests and maintains DMA master control of the system bus, and generates the appropriate memory command. The interface board also acknowledges I/O commands as required by the Intellec bus. In addition to supporting a second set of double density drives, the diskette controller may co-reside with the Intel single density controller to allow up to 2.5 million bytes of on-line storage.

MULTIBUS Capability

All Intellec Series II models implement the industry standard MULTIBUS. MULTIBUS enables several bus masters, such as CPU and DMA devices, to share the bus and memory by operating at different priority levels. Resolution of bus exchanges is synchronized by a bus clock signal derived independently from processor clocks. Read/write transfers may take place at rates up to 5 MHz. The bus structure is suitable for use with any Intel microcomputer family.

SPECIFICATIONS

Host Processor (IPB)

RAM — 64K (system monitor occupies 62K through 64K)
ROM — 4K (2K in monitor, 2K in boot/diagnostic)

Diskette System Capacity (Basic Two Drives)

Unformatted
Per Disk: 6.2 megabits
Per Track: 82.0 kilobits

Formatted
Per Disk: 4.1 megabits
Per Track: 53.2 kilobits

Diskette Performance

Diskette System Transfer Rate — 500 kilobits/sec

Diskette System Access Time
Track-to-Track: 10 ms
Head Settling Time: 10 ms

Average Random Positioning Time — 260 ms

Rotational Speed — 360 rpm
Average Rotational Latency — 83 ms
Recording Mode — M^2FM

Physical Characteristics

Width — 17.37 in. (44.12 cm)
Height — 15.81 in. (40.16 cm)
Depth — 19.13 in. (48.59 cm)
Weight — 73 lb (33 kg)

Keyboard
Width — 17.37 in. (44.12 cm)
Height — 3.0 in. (7.62 cm)
Depth — 9.0 in. (22.86 cm)
Weight — 6 lb (3 kg)

Dual Drive Chassis
Width — 16.88 in. (42.88 cm)
Height — 12.08 in. (30.68 cm)
Depth — 19.0 in. (48.26 cm)
Weight — 64 lb (29 kg)

Electrical Characteristics

DC Power Supply

Volts Supplied	Amps Supplied	Typical System Requirements
+ 5 ± 5%	30	14.25
+ 12 ± 5%	2.5	0.2
− 12 ± 5%	0.3	0.05
− 10 ± 5%	1.5	15
* + 15 ± 5%	1.5	1.3
* + 24 ± 5%	1.7	

*Not available on bus.

AC Requirements — 50/60 Hz, 115/230V AC

Environmental Characteristics

Operating Temperature — 0° to 35°C (95°F)

Equipment Supplied

Model 230 chassis
Integrated processor board (IPB)
I/O controller board (IOC)
32K RAM board
CRT and keyboard
Double density floppy disk controller (2 boards)
Dual drive floppy disk chassis and cables
2 floppy disk drives (512K byte capacity each)
ROM-resident system monitor
ISIS-II system diskette with MCS-80/MCS-85 macroassembler

Reference Manuals

9800558 — A Guide to Microcomputer Development Systems (SUPPLIED)

9800550 — Intellec Series II Installation and Service Guide (SUPPLIED)

9800306 — ISIS-II System User's Guide (SUPPLIED)

9800556 — Intellec Series II Hardware Reference Manual (SUPPLIED)

9800301 — 8080/8085 Assembly Language Programming Manual (SUPPLIED)

9800292 — ISIS-II 8080/8085 Assembler Operator's Manual (SUPPLIED)

9800605 — Intellec Series II Systems Monitor Source Listing (SUPPLIED)

9800554 — Intellec Series II Schematic Drawings (SUPPLIED)

Reference manuals are shipped with each product only if designated SUPPLIED (see above). Manuals may be ordered from any Intel sales representative, distributor office or from Intel Literature Department, 3065 Bowers Avenue, Santa Clara, California 95051.

ORDERING INFORMATION

Part Number	Description
MDS-230	Intellec Series II Model 230 microcomputer development system (110V/60 Hz)
MDS-231	Intellec Series II Model 230 microcomputer development system (220V/50 Hz)

ISIS-II
DISKETTE OPERATING SYSTEM
MICROCOMPUTER DEVELOPMENT SYSTEM

Supports up to two hard disk drives (4 platters), four double density drives and two single density drives, providing up to 17 megabytes of storage in one system with up to 200 files per diskette, and 992 files per disk platter

Relocating MCS-80/MCS-85™ macro-assembler contains extended macro and conditional assembly capability

Command file facility allows console commands to be submitted from disk file

Disk operating system functions callable from user programs

Disk system text editor provides string search, substitution, insertions, and deletion commands

Supports resident, high level programming languages, PL/M, FORTRAN, BASIC, and COBOL

Provides dynamic allocation and deallocation of disk sectors for variable length files

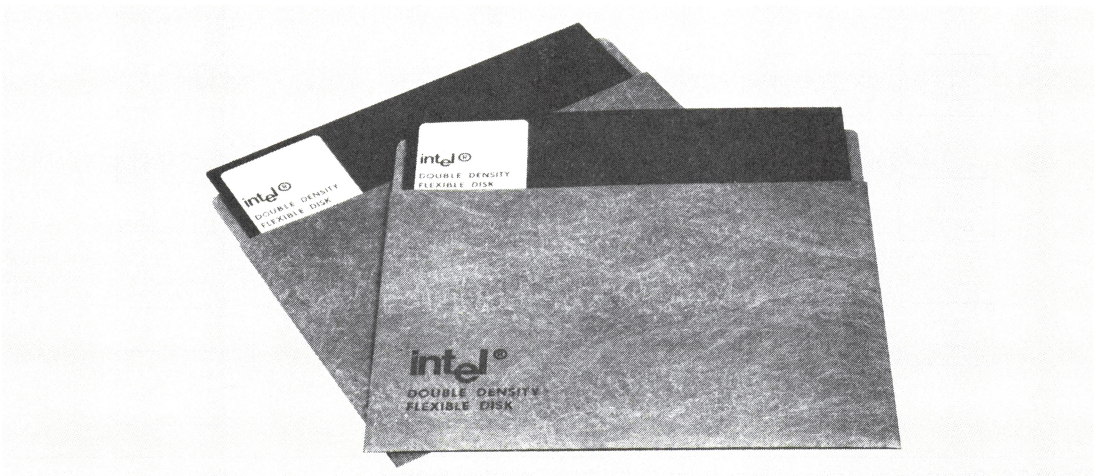
Linker automatically combines separately assembled or compiled programs into single relocatable module

Library manager™ creates and updates program libraries

Supports all standard Intellec® peripherals

Provides access to all Intellec® monitor facilities

The ISIS-II Microcomputer Development System Disk Operating System is a sophisticated, general purpose, high speed data handler and file manipulation system. It provides the ability to edit, assemble, compile, link, relocate, execute, and debug programs, and performs all user file management tasks. The ISIS-II operating system resides on the system disk and supports a broad range of user oriented design aid software. Total file management and input editing features greatly reduce software development time. The ISIS-II relocating macroassembler, linker, object locator, and library manager may be loaded from the disk in seconds. All passes of the assembler may be executed without the need for user intervention. Object code and listings may be directed to any output device, or stored as disk files. Powerful system console commands are provided in an easy to use context. Monitor mode may be entered by a special prefix to any system command or program call.



FUNCTIONAL DESCRIPTION

The ISIS-II operating system resides on the system disk and supports a broad range of user oriented design aid software. Total file management and input editing features greatly reduce software development time. The ISIS-II relocating macroassembler, linker, object locator, and library manager may be loaded from the disk in seconds. All passes of the assembler may be executed without the need for user intervention. Object code and listings may be directed to any output device, or stored as disk files. A diagram of the ISIS-II system program development flow is shown in Figure 7-6.

ISIS-II Files

A file is a user defined collection of information of variable length. ISIS-II also treats each of the standard Intellec system peripherals as files through preassignment of unique file names to each device. In this manner data may be copied from one device to another (i.e., tape reader to tape punch) using the same command required to copy one disk data file to another. ISIS-II provides automatic implementation of random access disk files. each file is identified by a user chosen name unique on its disk. Up to 200 files may be stored on each disk, 992 on each hard disk platter.

ISIS-II System Commands

ISIS-II system commands are designed to provide the user with a powerful, easy to use program and file manipulation capability. Several commands have the capability of operating on several files at once via the wildcard file naming convention. As an example, the command DELETE ★ .OBJ deletes all files in the disk directory with the suffix .OBJ. A summary of ISIS-II system commands is presented in Table 7-4.

Call Capability — The delete, rename, and attribute assignment commands, along with a set of file I/O routines, are callable from user written programs. This allows the user to open, close, read, and write disk files, access standard peripheral devices, write error messages, and load other programs via simple program call statements.

Command	Operation
Initialize disk	Initializes a diskette for use by the system. Requires only one disk drive.
Attribute assignment	Assigns specified attributes to a file, such as write-protect.
Copy	Creates copies of existing diskette files or transfers files from one device to another.
Delete	Removes a file from the diskette, thereby freeing space for allocation of other files.
Directory	Lists name, size, and attributes of files from a specified diskette directory.
Rename	Allows diskette files to be renamed.
Format	Initializes a diskette for use by the system. (Use with two or more drives.)
Debug	Loads a specified program from a diskette into memory and then transfers control to the Intellec monitor for execution and or debugging.
Submit	Provides capability for executing a series of ISIS-II commands previously written to a diskette file.

Additional commands are provided for support of the hard disk.

Table 7-4. ISIS-II System Commands

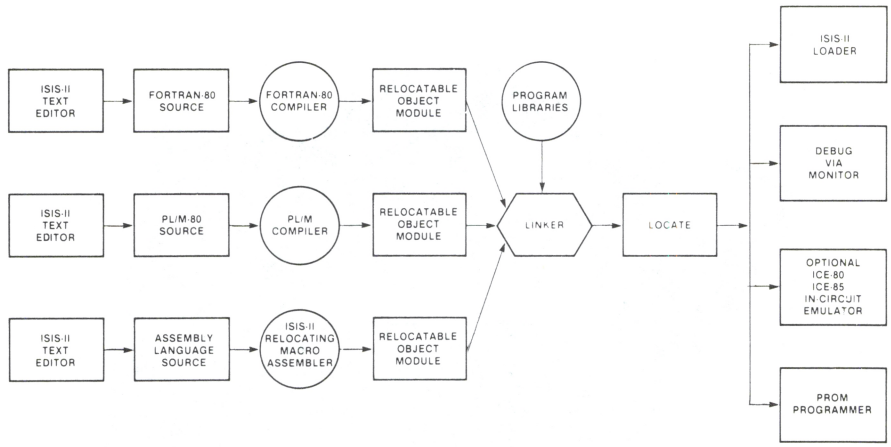


Figure 7-6. Program Development Flow Using ISIS-II Disk Operating System

ISIS-II Text Editor

The ISIS-II text editor is a comprehensive tool for assembly language, PL/M, and FORTRAN program entry and correction for Intel microcomputers. Its command set allows either entire lines of text or individual characters to be manipulated within a line.

Program Entry — Programs may be entered from the console keyboard or may be loaded directly. Text is stored internally in the editor's workspace, and may be edited with the following commands:

- string insertion or deletion
- string search
- string substitution

Utility Commands — To facilitate the use of these editing commands, utility commands are used to change positions in the workspace. These include:

- move pointer by line or by character
- move pointer to start of workspace
- move pointer to end of workspace

Storage — The contents of the workspace are stored on diskette and can be immediately accessed by ISIS-II commands or other programs, such as the ISIS-II MCS-80/MCS-85 macroassembler.

For users with 64K of RAM memory, the CREDIT Text Editor is available. See CREDIT data sheet for more information.

ISIS-II MCS-80/MCS-85™ Relocating Macroassembler

Address Translation — The ISIS-II MCS-80/MCS-85 macroassembler translates assembly language mnemonics into relocatable and/or absolute object code modules. In addition to eliminating the errors of hand translation, the ability to refer to program addresses with symbolic names makes it easy to modify programs by adding or deleting instructions. Extended macro capability eliminates the need to rewrite similar sections of code repeatedly, and thus simplifies program documentation. Conditional assembly permits the assembler to include or delete sections of code that may vary from system to system, such as the code required to handle optional external devices. Additionally, the user is allowed complete freedom in assigning the location of code, data, and stack segments.

List File — The ISIS-II Assembler accepts disk file input and produces a relocatable object file with corresponding symbol table and assembly listing file, including any error messages. A cross reference listing is also optionoptionally produced. The list file may then be examined from the system console or copied to a specified list device.

Object File — The relocatable object file generated by the assembler may be combined with other object programs residing on the disk to form a single relocatable object module or it can be converted to an absolute form for subsequent loading and execution.

ISIS-II Linker

The ISIS-II linker provides the capability to combine the outputs of several independently compiled or assembled object modules (files) into a single relocatable object module. The linker automatically resolves all external program and data references during the linking process. Object modules produced from previous link operations may be easily linked to a new module. ISIS-II also provides facilities to ease the generation of overlays. An optional link map showing the contents and lengths of each segment in the output module can be requested. All unsatisfied external references are also listed. If requested by the user, the ISIS-II linker can search a specified set of program libraries for routines to be included in the output module.

ISIS-II Object Locator

The ISIS-II locate program takes output from either the resident FORTRAN or PL/M compilers, the macroassembler, or the linker and transforms that output from relocatable format to an absolute format which may then be loaded via the standard ISIS-II loader, or loaded into an appropriate in-circuit emulator (ICE) module. During the locate process, code, data, and stack segments may be separately relocated, allowing code to be put in areas to be subsequently specified as ROM, while data and the stack are directed to RAM addresses. A locate map showing absolute addresses for each code and data segment and a symbol table dump listing symbols, attributes, and absolute address may also be requested.

ISIS-II Library Manager™

The ISIS-II Library Manager program provides for the creation and maintenance of a program library containing Intel-provided and user-written programs and subroutines. These library routines may be linked to a program using the ISIS-II linker. Several libraries, each containing its own set of routines, may be created.

ORDERING INFORMATION

Part Number	Description

Included with all Intellec Series II Microcomputer Development Systems.

Not available separately.

PL/M-80
HIGH LEVEL PROGRAMMING LANGUAGE
INTELLEC® RESIDENT COMPILER

Provides resident operation on Intellec® Microcomputer Development System and Intellec® Series II microcomputer development systems

Produces relocatable and linkable object code

Sophisticated code optimization reduces application memory requirements

Speeds project completion with increased programmer productivity

Cuts software development and maintenance costs

Improves product reliability with simplified language and consequent error reduction

Eases enhancement as system capabilities expand

The PL/M-80 High Level Programming Language Intellec Resident Compiler is an advanced, high level programming language for Intel 8080 and 8085 microprocessors, iSBC-80 OEM computer systems, and Intellec microcomputer development systems. PL/M has been substantially enhanced since its introduction in 1973 and has become one of the most effective and powerful microprocessor systems implementation tools available. It is easy to learn, facilitates rapid program development and debugging, and significantly reduces maintenance costs. PL/M is an algorithmic language in which program statements naturally express the algorithm to be programmed, thus freeing programmers to concentrate on system development rather than assembly language details (such as register allocation, meanings of assembler mnemonics, etc.). The PL/M compiler efficiently converts free-form PL/M programs into equivalent 8080/8085 instructions. Substantially fewer PL/M statements are necessary for a given application than would be using assembly language or machine code. Since PL/M programs are problem oriented and thus more compact, programming in PL/M results in a high degree of productivity during development efforts, resulting in significant cost reduction in software development and maintenance for the user.



FUNCTIONAL DESCRIPTION

The PL/M compiler is an efficient multiphase compiler that accepts source programs, translates them into object code, and produces requested listings. After compilation, the object program may be first linked to other modules, then located to a specific area of memory, and finally executed. The diagram shown in Figure 7-7 illustrates a program development cycle where the program consists of three modules: PL/M, FORTRAN, and assembly language. A typical PL/M compiler procedure is shown on the following page.

Features

Major features of the Intel PL/M-80 compiler and programming language include:

Resident Operation — on Intellec microcomputer development systems eliminates the need for a large in-house computer or costly timesharing system.

Object Code Generation — of relocatable and linkable object codes permits PL/M program development and debugging in small modules, which may be easily linked with other modules and/or library routines to form a complete application.

Extensive Code Optimization — including compile time arithmetic, constant subscript resolution, and common subexpression elimination, results in generation of short, efficient CPU instruction sequences.

Symbolic Debugging — fully supported in the PL/M compiler and ICE-85 in-circuit emulators.

Compile Time Options — includes general listing format commands, symbol table listing, cross reference listing, and "innerlist" of generated assembly language instructions.

Block Structure — aids in utilization of structured programming techniques.

Access — provided by high level PL/M statements to hardware resources (interrupt systems, absolute addresses, CPU input/output ports).

Data Definition — enables complex data structures to be defined at a high level.

Re-entrant Procedures — may be specified as a user option.

Benefits

PL/M is designed to be an efficient, cost-effective solution to the special requirements of microcomputer software development as illustrated by the following benefits of PL/M use:

Low Learning Effort — even for the novice programmer, because PL/M is easy to learn.

Earlier Project Completion — on critical projects, because PL/M substantially increases programmmer productivity while reducing program development time.

Lower Development Cost — because increased programmer productivity requiring less programming resources for a given function translates into lower software development costs.

Increased Reliability — because of PL/M's use of simple statements in the program algorithm, which are easier to correct and thus substantially reduce the risk of costly errors in systems that have already reached full production status.

Easier Enhancement and Maintenance — because programs written in PL/M are easier to read and easier to understand than assembly language, and thus are easier to enhance and maintain as system capabilities expand and future products are developed.

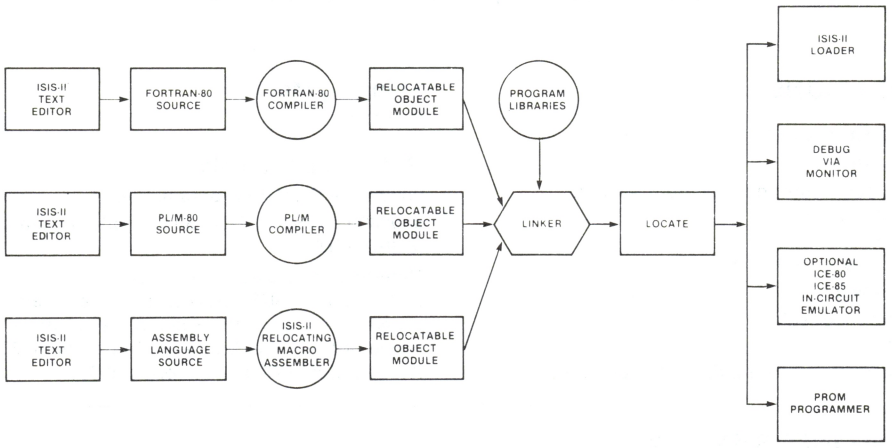


Figure 7-7. Program Development Cycle Block Diagram

Simpler Project Development — because the Intellec microcomputer development system with resident PL/M-80 is all that is needed for developing and debugging software for 8080 and 8085 microcomputers, and the use of expensive (and remote) timesharing or large computers is consequently not required.

```
                                        $OBJECT(:F1:FACT.OB2)
                                        $DEBUG
                                        $XREF
                                        $TITLE('FACTORIAL GENERATOR — PROCEDURE')
                                        $PAGEWIDTH(80)

 1                                      FACT:
                                        DO;

 2    1                                 DECLARE NUMCH BYTE PUBLIC;

 3    1                                 FACTORIAL: PROCEDURE (NUM,PTR) PUBLIC;
 4    2                                     DECLARE NUM BYTE, PTR ADDRESS;
 5    2                                     DECLARE DIGITS BASED PTR (161) BYTE;
 6    2                                     DECLARE (I,C,M) BYTE;

 7    2                                     NUMCH = 1; DIGITS(1) = 1;
 9    2                                     DO M = 1 TO NUM;
10    3                                         C = 0;
11    3                                         DO I = 1 TO NUMCH;
12    4                                             DIGITS(I) = DIGITS(I)*M + C;
13    4                                             C = DIGITS(I)/10;
14    4                                             DIGITS(I) = DIGITS(I) — 10*C;
15    4                                         END;

16    3                                         IF C<>0 THEN
17    3                                         DO;
18    4                                             NUMCH = NUMCH + 1; DIGITS(NUMCH) = C;
20    4                                             C = DIGITS(NUMCH)/10;
21    4                                             DIGITS(NUMCH) = DIGITS(NUMCH) — 10*C;
22    4                                         END
                                            END;

24    2                                 END FACTORIAL;

25    1                                 END;
```

PL/M-80 Compiler Sample Factorial Generator Procedure

SPECIFICATIONS

Operating Environment

Required Hardware

Intellec microcomputer development system
65K bytes of memory
Dual diskette drives
System console — teletype

Optional Hardware

CRT as system console
Line printer

Required Software — ISIS-II diskette operating system

Shipping Media

Diskette

Reference Manuals

980026 — PL/M-80 Programming Manual (SUPPLIED)

9800300 — ISIS-II PL/M-80 Compiler Operator's Manual (SUPPLIED)

Reference manuals are shipped with each product only if designated SUPPLIED (see above). Manuals may be ordered from any Intel sales representative, distributor office or from Intel Literature Department, 3065 Bowers Avenue, Santa Clara, California 95051.

ORDERING INFORMATION

Product Code	Description
MDS-PLM	High level language compiler

ICE-85™
MCS-85™ IN-CIRCUIT EMULATOR

Connects the Intellec® System Resources to the user-configured system via a 40-pin adaptor plug

Executes user system software in real-time

Allows user-configured system to share Intellec® memory and I/O facilities

Provides 1023 states of 8085 trace data plus 18 additional logic signals via an External Trace Module

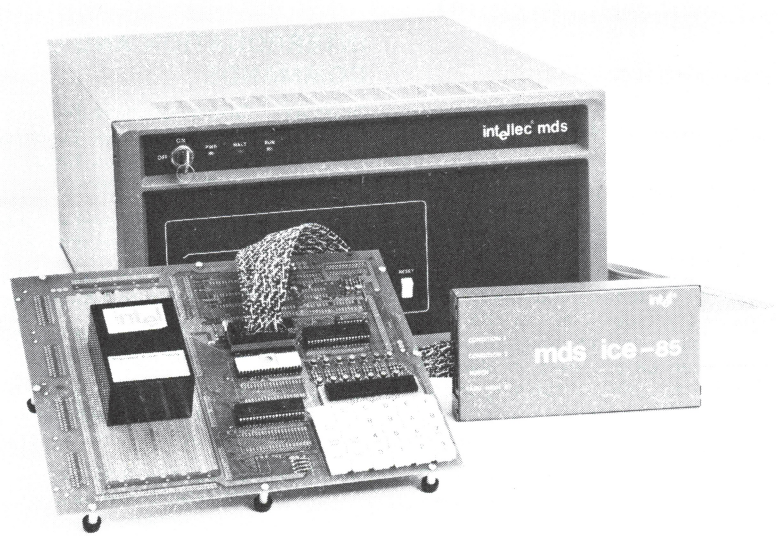
Offers full symbolic debugging capability for both assembly language and Intel's high-level compiler languages PL/M-80 and FORTRAN-80

Displays trace data from the user's 8085 in assembler mnemonics and allows personality groupings of data sampled by the external 18-channel trace module

Extends ICE capabilities to the rest of the prototype system peripheral circuitry by allowing the user to execute his own peripheral chip analysis routines

Provides ability to examine and alter MCS-85™ registers, memory, flag values, interrupt bits and I/O ports

The ICE-85 module resides in the Intellec® Microcomputer Development System and interfaces to the user system's 8085. In addition, an external trace module provides access to user system peripheral circuitry via a user-configured DIP clip for peripheral ICs or may be attached to as many as 18 separate prototype signal nodes via individual probe clips. Using the ICE-85 module, the designer can execute prototype software in real-time or single-step mode and can substitute Intellec® system memory and I/O for user system equivalent. ICE capability can be extended to the rest of the user system peripheral circuitry by allowing the user to create and execute a library of user-defined peripheral chip analyzer routines. All user access to the prototype system software may be done symbolically by assigning names to program locations and data, I/O ports and groups of external trace signals. For the first time, in-circuit emulation extends beyond the user's prototype CPU to the entire user's system, allowing In-System Emulation.



SYMBOLIC DEBUGGING CAPABILITY

ICE-85 allows the user to make symbolic references to I/O ports, memory addresses and data in his program. Symbols and PL/M-80 statement number may be substituted for numeric values in any of the ICE-85 commands. The user is relieved from looking up addresses of variables or program subroutines.

The user symbol table generated along with the object file during a PL/M-80 or FORTRAN-80 compilation or by the ISIS-II 8080/8085 Macro Assembler is loaded into the Intellec® System memory along with the user program which is to be emulated. The user may add to this symbol table any additional symbolic values for memory addresses, constants, or variables that are found useful during system debugging. By referring to symbol memory addresses, the user can examine, change or break at the intended location.

ICE-85 provides symbolic definition of all 8085 registers, interrupt bits and flags. The following symbolic references are also provided for user convenience: TIMER, the low-order 16 bits of a register containing the number of 2 MHz clock pulses elapsed during emulation; HTIMER, the high-order 16 bits of the timer counter; PPC, the address of the last instruction emulated; BUFFERSIZE, the number of frames of valid trace data (between 0 and 1022).

PERSONALITY GROUPED DISPLAYS

Trace data in the 1023 by 42-channel real-time trace memory buffer is displayed in easy to read format. The user has the option to specify trace data displays in actual 8085 assembler instruction mnemonics. The data collected from the External Trace Module can be grouped and symbolically named according to user specifications and displayed in the appropriate number base designation. Simple ICE-85 commands allow the user to select any portion of the 42K-bit trace buffer for immediate display.

MEMORY AND I/O MAPPING

Memory and I/O for the user system can be resident in the user system or "borrowed" from the Intellec® System through ICE-85's mapping capability.

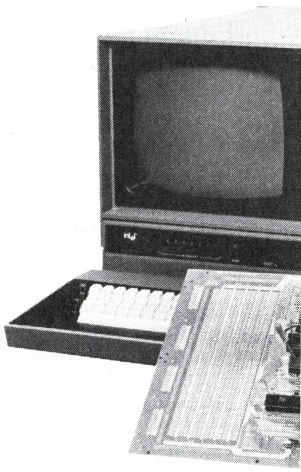
ICE-85 separates user memory into 32 2K blocks. Each block of memory can be defined independently. The user may assign Intellec® System equivalents to take the place of devices not yet designed for the user system during prototyping. In addition, Intellec® System memory or I/O can be accessed in place of suspect user system devices during prototyping or production checkout.

The user can also designate a block of memory or I/O as nonexistent. ICE-85 issues error messages when memory or I/O designated as nonexistent is accessed by the user program.

INTEGRATED HARDWARE/SOFTWARE DEVELOPMENT

The user prototype need consist of no more than an 8085 CPU socket and a user bus to begin integration of software and hardware development efforts. Through ICE-85 mapping capabilities, Intellec® System equivalents can be accessed for missing prototype hardware. Hardware designs can be tested using the system software which will drive the final product.

The system integration phase, which can be so costly when attempting to mesh completed hardware and software products, becomes a convenient two-way debug tool when begun early in the design cycle.



INTERROGATION AND UTILITY COMMANDS

DISPLAY/ CHANGE	Display/Changes the values of symbols and the contents of 8085 registers, pseudo-registers, status flags, interrupt bits, I/O ports and memory.
EVALUATE	Displays the value of an expression in the binary, octal, decimal or hexadecimal.
SEARCH	Searches user memory between locations in a user program for specified contents.
CALL	*Emulates* a procedure starting at a specified memory address in user memory.
ICALL	*Executes* a user-supplied procedure starting at a specified memory address in the Intellec® System memory.
EXECUTE	Saves emulated program registers and emulates a user-supplied subroutine to access peripheral chips in the user's system.

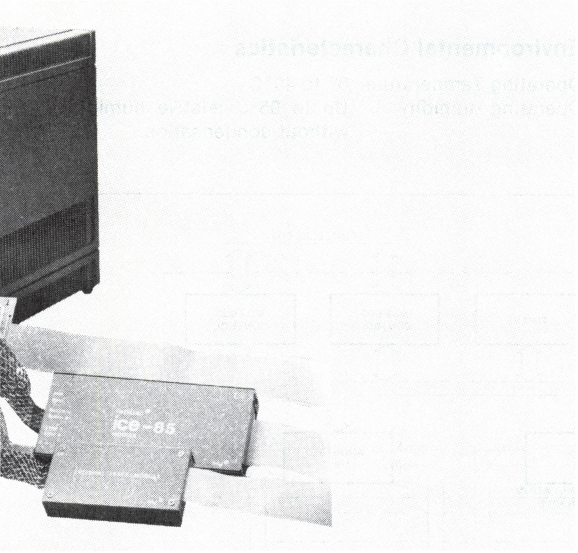
REAL TIME TRACE

ICE-85 captures valuable trace information from the emulating CPU and the External Trace Module while the user is executing programs in real time. The 8085 status, the user memory or port addressed, the data read or written, the serial data lines and data from 18 external signals, is stored for the last 1023 machine states executed (511 machine cycles). This provides ample data for determining how the user system was reacting prior to emulation break. It is available whether the break was user-initiated or the result of an error condition.

For detailed information on the actions of CPU registers, flags, or other system operations, the user may operate in single or multi-step sequences tailored to system debug needs.

EXTERNAL TRACE MODULE

TTL level signals from 18 points in the user system may be synchronously sampled by the External Trace Module and collected in ICE-85's trace buffer. The signals can be collected from a single peripheral chip via the supplied 40-pin DIP clip or may be placed by the user on up to 18 separate signal nodes using the supplied 18 individual probe clips. These signals are included in the 42-channel breakpoint comparisons and clock qualifiers. Also, data from these 18 channels may be displayed in each to read, user-defined groupings.



SYNCHRONOUS OPERATION WITH OTHER DESIGN AIDS

ICE-85 can be synchronized with other Intellec® design aids by means of two external synchronization lines. These lines are used to enable and disable ICE-85 trace data collection and to cause break conditions based on an external signal which may not be included in the ICE-85 breakpoint registers. In addition, ICE-85 can generate signals on these lines which may be used to control other design aids.

EMULATION CONTROLS AND COMMANDS

GROUP — Defines into a symbolically named group, a channel or combination of channels from the 8085 Microprocessor and/or the External Trace Module.

GO — Initiates real-time emulation and controls emulation break conditions.

STEP — Initiates emulation in single instruction steps. User may specify the type and amount of information displayed following each step, and define conditions under which stepping should continue.

PRINT — Prints the user-specified portion of the trace memory to the selected list device.

BREAK REGISTERS/TRACE MEMORY

ICE-85 has two breakpoint registers which are used to break emulation, and two trace qualifier registers which are used to control the collection of trace data during emulation. Each register is 42 entries wide, one entry for each channel and each entry can take any one of the three values 0, 1 or "don't care."

The trace buffer, also 42 entries wide, collects data sampled from 24 8085 processor channels and 18 external channels sampled by the External Trace Module. The signals collected from the 8085 include address lines, data lines, status lines and series input and output lines. The 18 channels extending from the External Trace Module synchronously sample and collect into the trace buffer any user-specified TTL compatible signal from the rest of the prototype system. "Break" and "trace qualification" may therefore occur as a result of a match of any combination of up to 42 channels of CPU and external circuitry signals.

SPECIFICATIONS

ICE-85 Operating Environment

Required Hardware:
- Intellec® Microcomputer Development System
- System Console
- Intellec® Diskette Operating System
- ICE-85 Module

Required Software:
- System Monitor
- ISIS-II
- ICE-85 Software

Equipment Supplied

18-Channel External Trace Module
Printed Circuit Boards (2)
Interface Cable and Emulation Buffer Module
Operator's Manual
ICE-85 Software, Diskette-Based Version

Emulation Clock

User's system clock or ICE-85 adaptor socket (6.144 MHz Crystal)

Physical Characteristics

Printed Circuit Boards:

Width:	12.00 in. (30.48 cm)
Height:	6.75 in. (17.15 cm)
Depth:	0.50 in. (1.27 cm)
Packaged Weight:	6.00 lb (2.73 kg)

Electrical Characteristics

DC Power:
- $V_{CC} = +5V \pm 5\%$
- $I_{CC} = 12A$ maximum; 10A typical
- $V_{DD} = +12V \pm 5\%$
- $I_{DD} = 80$ mA maximum; 60 mA typical
- $V_{BB} = -10V \pm 5\%$
- $I_{BB} = 1$ mA maximum; 10 μA typical

Environmental Characteristics

Operating Temperature: 0° to 40°C
Operating Humidity: Up to 95% relative humidity without condensation.

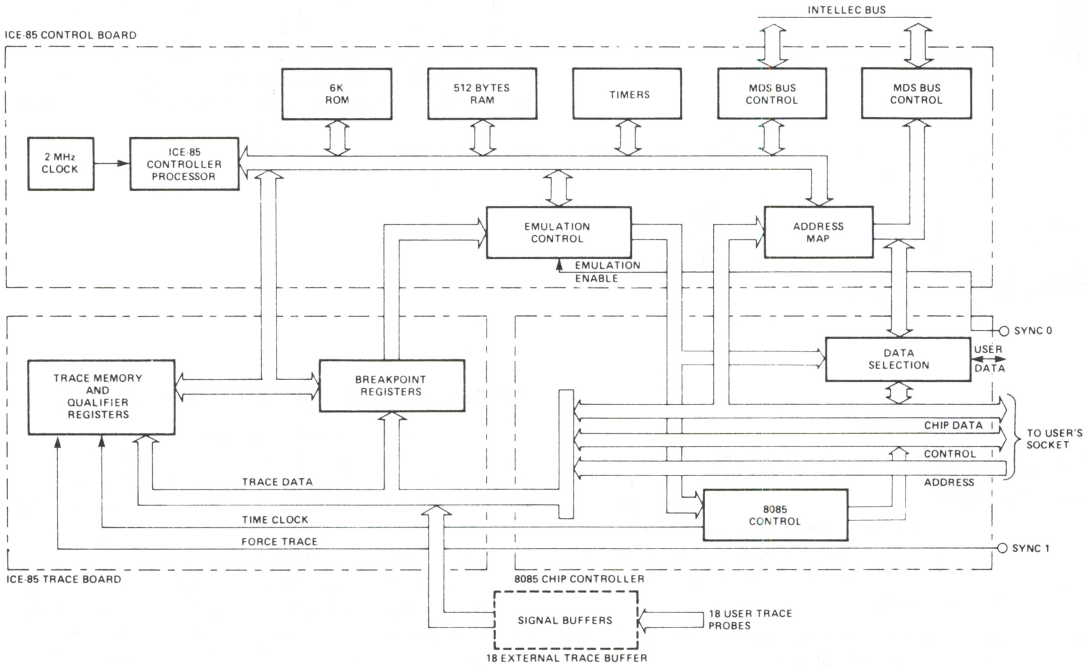


Figure 7-8. ICE-85 Block Diagram

Ordering Information

Part Number	Description
MDS-85-ICE	8085 CPU In-Circuit Emulator and 18-Channel External Trace Module

SDK-85
MCS-85™ SYSTEM DESIGN KIT

Complete single board microcomputer system including CPU, memory, and I/O

Easy to assemble, low cost, kit form

Extensive system monitor software in ROM

Interactive LED display and keyboard

Large wire-wrap area for custom interfaces

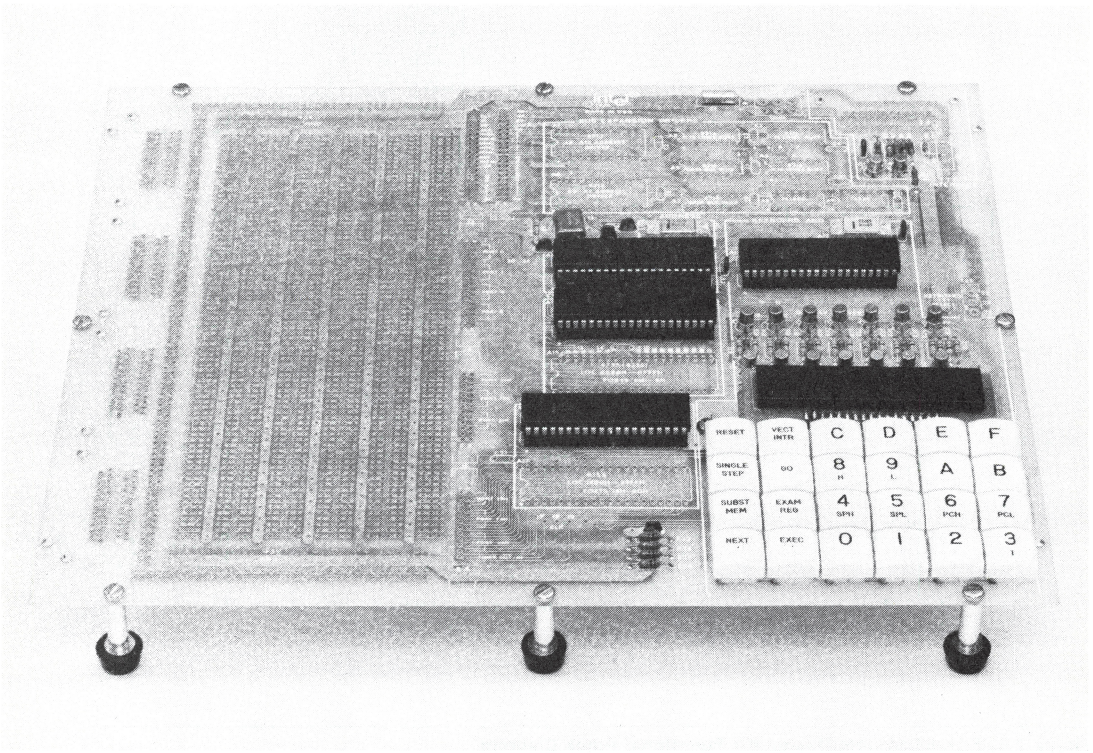
Popular 8080A instruction set

Interfaces directly with TTY

High performance 3 MHz 8085A CPU (1.3 μs instruction cycle)

Comprehensive design library included

The SDK-85 MCS-85 System Design Kit is a complete single board microcomputer system in kit form. It contains all components required to complete construction of the kit, including LED display, keyboard, resistors, caps, crystal, and miscellaneous hardware. Included is a preprogrammed ROM containing a system monitor for general software utilities and system diagnostics. The complete kit includes a 6-digit LED display and a 24-key keyboard for a direct insertion, examination, and execution of a user's program. In addition, it can be directly interfaced with a teletype terminal. The SDK-85 is an inexpensive, high performance prototype system that has designed-in flexibility for simple interface to the user's application.



FUNCTIONAL DESCRIPTION

The SDK-85 is a complete 8085A microcomputer system on a single board, in kit form. It contains all necessary components to build a useful, functional system. Such items as resistors, capacitors, and sockets are included. Assembly time varies from three to five hours, depending on the skill of the user. The SDK-85 functional block diagram is shown in Figure 7-9.

8085A Processor

The SDK-85 is designed around Intel's 8085A microprocessor. The Intel 8085A is a new generation, complete 8-bit parallel central processing unit (CPU). Its instruction set is 100% software upward compatible with the 8080A microprocessor, and it is designed to improve the present 8080A's performance by higher system speed. Its high level of system integration allows a minimum system of three IC's: 8085A (CPU), 8156 (RAM), and 8355/8755 (ROM/PROM). A block diagram of the 8085A microprocessor is shown in Figure 7-10.

System Integration — The 8085A incorporates all of the features that the 8224 (clock generator) and 8228 (system controller) provided for the 8080A, thereby offering a high level of system integration.

Addressing — The 8085A uses a multiplexed data bus. The 16-bit address is split between the 8-bit address bus and the 8-bit address/data bus. The on-chip address latches of 8155/8156/8355/8755 memory products allows a direct interface with the 8085A.

System Monitor

A compact but powerful system monitor is supplied with the SDK-85 to provide general software utilities and system diagnostics. It comes in a pre-programmed ROM.

Communications Interface

The SDK-85 communicates with the outside world through either the on-board LED display/keyboard combination, or the user's TTY terminal (jumper selectable).

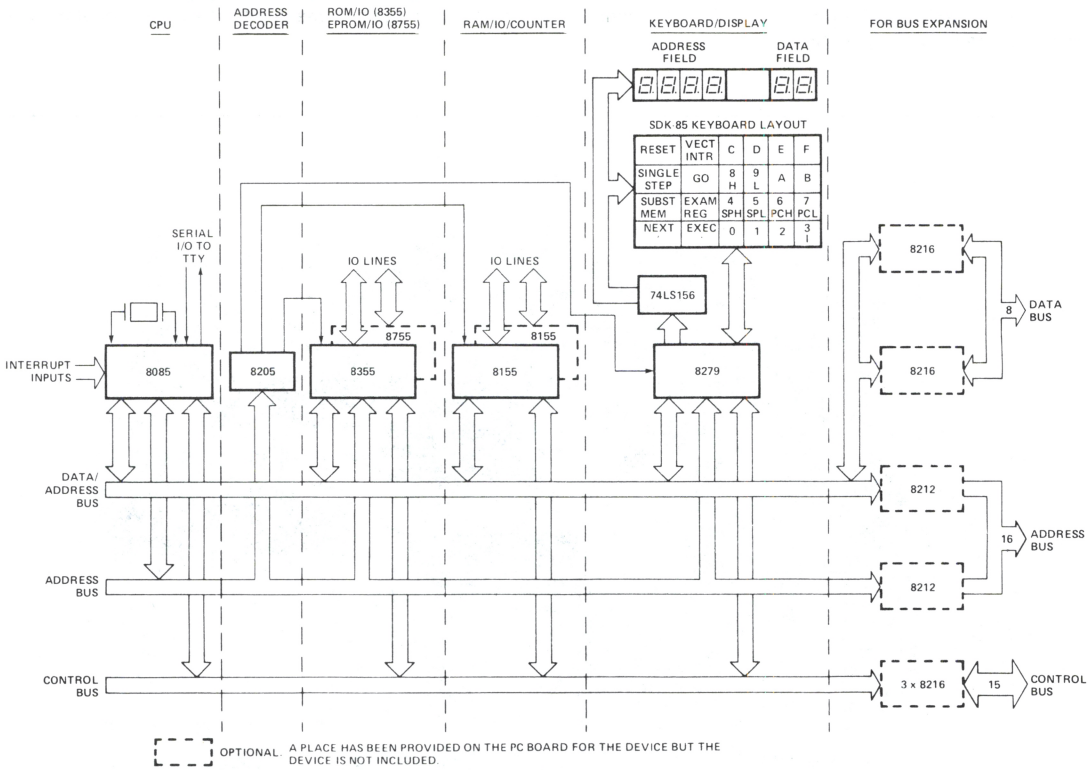
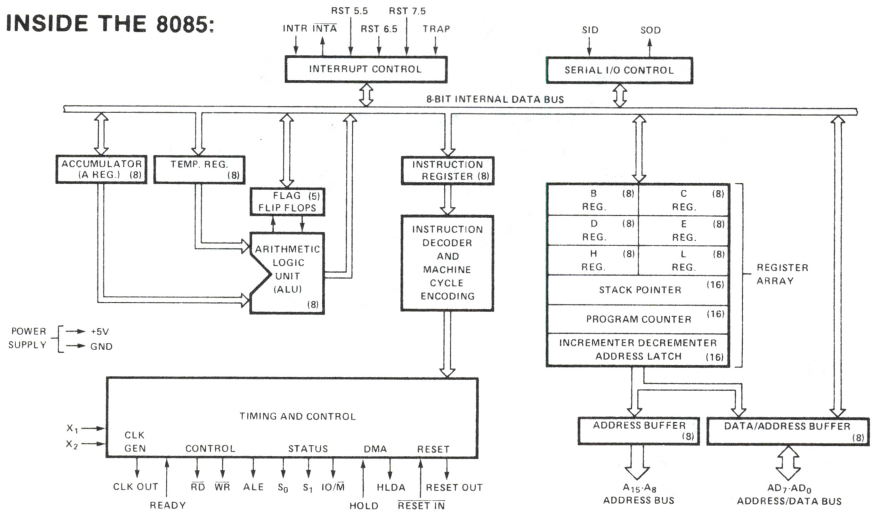


Figure 7-9. SDK-85 System Design Kit Functional Block Diagram



- SEVEN 8-BIT REGISTERS. SIX OF THEM CAN BE LINKED IN REGISTER PAIRS FOR CERTAIN OPERATIONS.
- 8-BIT ALU.
- 16-BIT STACK POINTER (STACK IS MAINTAINED OFFBOARD IN SYSTEM RAM MEMORY).
- 16-BIT PROGRAM COUNTER.

Figure 7-10. 8085A Microprocessor Block Diagram

Both memory and I/O can be easily expanded by simply soldering in additional devices in locations provided for this purpose. A large area of the board (45 sq. in.) is laid out as general purpose wire-wrap for the user's custom interfaces.

Assembly

Only a few simple tools are required for assembly; soldering iron, cutters, screwdriver, etc. The SDK-85 user's manual contains step-by-step instructions for easy assembly without mistakes. Once construction is complete, the user connects his kit to a power supply and the SDK-85 is ready to go. The monitor starts immediately upon power-on or reset.

Command	Operation
Reset	Starts monitor.
Go	Allows user to execute user program.
Single step	Allows user to execute user program one instruction at a time—useful for debugging.
Substitute memory	Allows user to examine and modify memory locations.
Examine register	Allows user to examine and modify 8085A's register contents.
Vector interrupt	Serves as user interrupt button.

Table 7-5. Keyboard Monitor Commands

Commands — Keyboard monitor commands and teletype monitor commands are provided in Table 7-5 and Table 7-6, respectively.

Command	Operation
Display memory	Displays multiple memory locations.
Substitute memory	Allows user to examine and modify memory locations one at a time.
Insert instructions	Allows user to store multiple bytes in memory.
Move memory	Allows user to move blocks of data in memory.
Examine register	Allows user to examine and modify the 8085A's register contents.
Go	Allows user to execute user programs.

Table 7-6. Teletype Monitor Commands

Documentation

In addition to detailed information on using the monitors, the SDK-85 user's manual provides circuit diagrams, a monitor listing, and a description of how the system works. The complete design library for the SDK-85 is shown in Figure 7-11 and listed in the Specifications section under Reference Manuals.



Figure 7-11. SDK-85 Design Library

8085A INSTRUCTION SET

Table 7-7 contains a summary of processor instructions used for the 8085A microprocessor.

Mnemonic[1]	Description	Instruction Code[2] D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	Clock[3] Cycles
MOVE, LOAD, AND STORE										
MOVr1r2	Move register to register	0	1	D	D	D	S	S	S	4
MOV M,r	Move register to memory	0	1	1	1	0	S	S	S	7
MOV r,M	Move memory to register	0	1	D	D	D	1	1	0	7
MVI r	Move immediate register	0	0	D	D	D	1	1	0	7
MVI M	Move immediate memory	0	0	1	1	0	1	1	0	10
LXI B	Load immediate register Pair B & C	0	0	0	0	0	0	0	1	10
LXI D	Load immediate register Pair D & E	0	0	0	1	0	0	0	1	10
LXI H	Load immediate register Pair H & L	0	0	1	0	0	0	0	1	10
STAX B	Store A indirect	0	0	0	0	0	0	1	0	7
STAX D	Store A indirect	0	0	0	1	0	0	1	0	7
LDAX B	Load A indirect	0	0	0	0	1	0	1	0	7
LDAX D	Load A indirect	0	0	0	1	1	0	1	0	7
STA	Store A direct	0	0	1	1	0	0	1	0	13
LDA	Load A direct	0	0	1	1	1	0	1	0	13
SHLD	Store H & L direct	0	0	1	0	0	0	1	0	16
LHLD	Load H & L direct	0	0	1	0	1	0	1	0	16
XCHG	Exchange D & E, H & L registers	1	1	1	0	1	0	1	1	4
STACK OPS										
PUSH B	Push register pair B & C on stack	1	1	0	0	0	1	0	1	12
PUSH D	Push register pair D & E on stack	1	1	0	1	0	1	0	1	12
PUSH H	Push register pair H & L on stack	1	1	1	0	0	1	0	1	12
PUSH PSW	Push A and flags on stack	1	1	1	1	0	1	0	1	12
POP B	Pop register pair B & C off stack	1	1	0	0	0	0	0	1	10
POP D	Pop register pair D & E off stack	1	1	0	1	0	0	0	1	10
POP H	Pop register pair H & L off stack	1	1	1	0	0	0	0	1	10
POP PSW	Pop A and flags off stack	1	1	1	1	0	0	0	1	10
XTHL	Exchange top of stack, H & L	1	1	1	0	0	0	1	1	16
SPHL	H & L to stack pointer	1	1	1	1	1	0	0	1	6
LXI SP	Load immediate stack pointer	0	0	1	1	0	0	0	1	10
INX SP	Increment stack pointer	0	0	1	1	0	0	1	1	6
DCX SP	Decrement stack pointer	0	0	1	1	1	0	1	1	6
JUMP										
JMP	Jump unconditional	1	1	0	0	0	0	1	1	10
JC	Jump on carry	1	1	0	1	1	0	1	0	7/10
JNC	Jump on no carry	1	1	0	1	0	0	1	0	7/10
JZ	Jump on zero	1	1	0	0	1	0	1	0	7/10
JNZ	Jump on no zero	1	1	0	0	0	0	1	0	7/10
JP	Jump on positive	1	1	1	1	0	0	1	0	7/10
JM	Jump on minus	1	1	1	1	1	0	1	0	7/10
JPE	Jump on parity even	1	1	1	0	1	0	1	0	7/10
JPO	Jump on parity odd	1	1	1	0	0	0	1	0	7/10
PCHL	H & L to program counter	1	1	1	0	1	0	0	1	6
CALL										
CALL	Call unconditional	1	1	0	0	1	1	0	1	18
CC	Call on carry	1	1	0	1	1	1	0	0	9/18
CNC	Call on no carry	1	1	0	1	0	1	0	0	9/18
CZ	Call on zero	1	1	0	0	1	1	0	0	9/18
CNZ	Call on no zero	1	1	0	0	0	1	0	0	9/18
CP	Call on positive	1	1	1	1	0	1	0	0	9/18
CM	Call on minus	1	1	1	1	1	1	0	0	9/18
CPE	Call on parity even	1	1	1	0	1	1	0	0	9/18
CPO	Call on parity odd	1	1	1	0	0	1	0	0	9/18
RETURN										
RET	Return	1	1	0	0	1	0	0	1	10
RC	Return on carry	1	1	0	1	1	0	0	0	6/12
RNC	Return on no carry	1	1	0	1	0	0	0	0	6/12
RZ	Return on zero	1	1	0	0	1	0	0	0	6/12
RNZ	Return on no zero	1	1	0	0	0	0	0	0	6/12
RP	Return on positive	1	1	1	1	0	0	0	0	6/12
RM	Return on minus	1	1	1	1	1	0	0	0	6/12

continued

Mnemonic[1]	Description	Instruction Code[2] D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	Clock[3] Cycles
RPE	Return on parity even	1	1	1	0	1	0	0	0	6/12
RPO	Return on parity odd	1	1	1	0	0	0	0	0	6/12
RESTART										
RST	Restart	1	1	A	A	A	1	1	1	12
INCREMENT AND DECREMENT										
INR r	Increment register	0	0	D	D	D	1	0	0	4
DCR r	Decrement register	0	0	D	D	D	1	0	1	4
INR M	Increment memory	0	0	1	1	0	1	0	0	10
DCR M	Decrement memory	0	0	1	1	0	1	0	1	10
INX B	Increment B & C registers	0	0	0	0	0	0	1	1	6
INX D	Increment D & E registers	0	0	0	1	0	0	1	1	6
INX H	Increment H & L registers	0	0	1	0	0	0	1	1	6
DCX B	Decrement B & C	0	0	0	0	1	0	1	1	6
DCX D	Decrement D & E	0	0	0	1	1	0	1	1	6
DCX H	Decrement H & L	0	0	1	0	1	0	1	1	6
ADD										
ADD r	Add register to A	1	0	0	0	0	S	S	S	4
ADC r	Add register to A with carry	1	0	0	0	1	S	S	S	4
ADD M	Add memory to A	1	0	0	0	0	1	1	0	7
ADC M	Add memory to A with carry	1	0	0	0	1	1	1	0	7
ADI	Add immediate to A	1	1	0	0	0	1	1	0	7
ACI	Add immediate to A with carry	1	1	0	0	1	1	1	0	7
DAD B	Add B & C to H & L	0	0	0	0	1	0	0	1	10
DAD D	Add D & E to H & L	0	0	0	1	1	0	0	1	10
DAD H	Add H & L to H & L	0	0	1	0	1	0	0	1	10
DAD SP	Add stack pointer to H & L	0	0	1	1	1	0	0	1	10
SUBTRACT										
SUB r	Subtract register from A	1	0	0	1	0	S	S	S	4
SBB r	Subtract register from A with borrow	1	0	0	1	1	S	S	S	4
SUB M	Subtract memory from A	1	0	0	1	0	1	1	0	7
SBB M	Subtract memory from A with borrow	1	0	0	1	1	1	1	0	7
SUI	Subtract immediate from A	1	1	0	1	0	1	1	0	7
SBI	Subtract immediate from A with borrow	1	1	0	1	1	1	1	0	7
LOGICAL										
ANA r	And register with A	1	0	1	0	0	S	S	S	4
XRA r	Exclusive Or register with A	1	0	1	0	1	S	S	S	4
ORA r	Or register with A	1	0	1	1	0	S	S	S	4
CMP r	Compare register with A	1	0	1	1	1	S	S	S	4
ANA M	And memory with A	1	0	1	0	0	1	1	0	7
XRA M	Exclusive Or memory with A	1	0	1	0	1	1	1	0	7
ORA M	Or memory with A	1	0	1	1	0	1	1	0	7
CMP M	Compare memory with A	1	0	1	1	1	1	1	0	7
ANI	And immediate with A	1	1	1	0	0	1	1	0	7
XRI	Exclusive Or immediate with A	1	1	1	0	1	1	1	0	7
ORI	Or immediate with A	1	1	1	1	0	1	1	0	7
CPI	Compare immediate with A	1	1	1	1	1	1	1	0	7
ROTATE										
RLC	Rotate A left	0	0	0	0	0	1	1	1	4
RRC	Rotate A right	0	0	0	0	1	1	1	1	4
RAL	Rotate A left through carry	0	0	0	1	0	1	1	1	4
RAR	Rotate A right through carry	0	0	0	1	1	1	1	1	4
SPECIALS										
CMA	Complement A	0	0	1	0	1	1	1	1	4
STC	Set carry	0	0	1	1	0	1	1	1	4
CMC	Complement carry	0	0	1	1	1	1	1	1	4
DAA	Decimal adjust A	0	0	1	0	0	1	1	1	4
INPUT/OUTPUT										
IN	Input	1	1	0	1	1	0	1	1	10
OUT	Output	1	1	0	1	0	0	1	1	10
CONTROL										
EI	Enable interrupts	1	1	1	1	1	0	1	1	4
DI	Disable interrupts	1	1	1	1	0	0	1	1	4
NOP	No-operation	0	0	0	0	0	0	0	0	4
HLT	Halt	0	1	1	1	0	1	1	0	5
NEW 8085 INSTRUCTIONS										
RIM	Read interrupt mask	0	0	1	0	0	0	0	0	4
SIM	Set interrupt mask	0	0	1	1	0	0	0	0	4

Notes

1. All mnemonics copyright © Intel Corporation 1977.
2. DDD or SSS: B = 000, C = 001, D = 010, E = 011, H = 100, L = 101, Memory = 110, A = 111.
3. Two possible cycle times. (6/12) indicates instruction cycles dependent on condition flags.

Table 7-7. Summary of 8085A Processor Instructions

SPECIFICATIONS

Central Processor

CPU — 8085A
Instruction Cycle — 1.3 μs
Tcy — 330 ns

Memory

ROM — 2K bytes (expandable to 4K bytes) 8355/8755A
RAM — 256 bytes (expandable to 512 bytes) 8155

Addressing

ROM — 0000-07FF (expendable to 0FFF with an additional 8355/8755A)

RAM — 2000-20FF (2800-28FF available with an additional 8155)

Note
The wire-wrap area of the SDK-85 PC board may be used for additional custom memory expansion up to the 64K-byte addressing limit of the 8085A.

Input/Output

Parallel — 38 lines (expandable to 76 lines)

Serial — Through SID/SOD ports of 8085A. Software generated baud rate.

Baud Rate — 110

Interfaces

Bus — All signals TTL compatible
Parallel I/O — All signals TTL compatible
Serial I/O — 20 mA current loop TTY

Note
By populating the buffer area of the board, the user has access to all bus signals that enable him to design custom system expansions into the kit's wire-wrap area.

Interrupts

Three Levels
(RST 7.5) — Keyboard interrupt
(RST 6.5) — TTL input
(INTR) — TTL input

DMA

Hold Request — Jumper selectable. TTL compatible input.

Software

System Monitor — Pre-programmed 8755A or 8355 ROM
Addresses — 0000-07FF
Monitor I/O — Keyboard/display or TTY (serial I/O)

Physical Characteristics

Width — 12.0 in. (30.5 cm)
Height — 10 in. (25.4 cm)
Depth — 0.50 in. (1.27 cm)
Weight — approx. 12 oz

Electrical Characteristics

DC Power Requirement (power supply not included in kit)

Voltage	Current
V_{CC} 5V ± 5%	1.3A
V_{TTY} – 10V ± 10%	0.3A (V_{TTY} required only if teletype is connected)

Environmental Characteristics

Operating Temperature — 0-55°C

Reference Manuals

9800451 — SDK-85 User's Manual (SUPPLIED)

9800366 — MCS-85 User's Manual (SUPPLIED)

9800301 — 8080/8085 Assembly Language Programming Manual (SUPPLIED)

8085/8080 Assembly Language Reference Card (SUPPLIED)

Reference manuals are shipped with each product only if designated SUPPLIED (see above). Manuals may be ordered from any Intel sales representative, distributor office or from Intel Literature Department, 3065 Bowers Avenue, Santa Clara, California 95051.

ORDERING INFORMATION

Part Number	Description
SDK-85	MCS-85 system design kit

FORTRAN-80
8080/8085 ANS FORTRAN 77
INTELLEC® RESIDENT COMPILER

Meets and exceeds ANS FORTRAN 77 Subset Language Specification

Supports Intel Floating Point Standard with either the floating point support library or the iSBC-310 High Speed Mathematics Board

Resident operation on Intellec® Microcomputer Development System and Intellec® Series II Microcomputer Development System

Supports full symbolic debugging with ICE-80™ and ICE-85™

Produces relocatable and linkable object code compatible with resident PL/M-80 and 8080/8085 Macro Assembler

Full FORTRAN 77 language I/O support or optional RMX-80 run-time library

Well defined I/O interface for configuration with user-supplied drivers

Sophisticated code optimization insures efficient program implementation

FORTRAN-80 is a computer industry-standard, high-level programming language and compiler that translates FORTRAN statements into relocatable object modules. When the object modules are linked together and located into absolute program modules, they are suitable for execution on Intel® 8080/8085 Microprocessors, iSBC-80 OEM Computer Systems, and Intellec® Microcomputer Development Systems. FORTRAN-80 meets and exceeds the ANS FORTRAN 77 Language Subset Specification[1]. The compiler operates on the Intellec Microcomputer Development System under the ISIS-II Disk Operating Systems and produces efficient relocatable object modules that are compatible for linkage with PL/M-80 and 8080/8085 Macro Assembler modules.

The ANS FORTRAN 77 language specification offers many powerful extensions to the FORTRAN language that are especially well suited to Intel® 8080/8085 Microprocessor software development. Because FORTRAN-80 conforms to the ANS FORTRAN 77 standard, the user is assured of compatibility with existing FORTRAN software that meets the standard as well as a guarantee of upward compatibility to other computer systems supporting an ANS FORTRAN 77 Compiler.

[1] ANSI X3J3/90



FORTRAN-80 LANGUAGE FEATURES

Major ANS FORTRAN 77 features supported by the Intel® FORTRAN-80 Programming Language include:

- Structured Programming is supported with the IF ... THEN ... ELSE IF ... ELSE ... END IF constructs.
- CHARACTER data type permits alphanumeric data to be handled as strings rather than characters stored in array elements.
- Full I/O capabilities include:
  - — Sequential and Direct Access files
  - — Error handling facilities
  - — Formatted, Free-formatted, and Unformatted data representation
  - — Internal (in-memory) file units provide capability to format and reformat data in internal memory buffers
  - — List Directed Formatting
- Supports arrays of up to seven dimensions.
- Supports logical operators
  .EQV. — Logical equivalence
  .NEQV. — Logical nonequivalence

Major extensions to FORTRAN 77 in Intel FORTRAN-80 include:

- Direct 8080/8085 port I/O supported by intrinsic subroutines.
- Binary and Hexadecimal integer constants.
- Well defined interface to FORTRAN-80 I/O statements (READ, OPEN, etc.), allowing easy use of user-supplied I/O drivers.
- User-defined INTEGER storage lengths of 1, 2 or 4 bytes.
- User-defined LOGICAL storage lengths of 1, 2 or 4 bytes.
- REAL STORAGE lengths of 4 bytes.
- Bitwise Boolean operations using logical operators on integer values.
- Hollerith data constants.
- Implicit extension of the length of an integer or logical expression to the length of the left-hand side in an assignment statement.
- A format descriptor to suppress carriage return on a terminal output device at the end of the record.

FORTRAN-80 COMPILER FEATURES

- Supports multiple compilation units in single source file.
- Optional Assembly Language code listing.
- Comprehensive cross-reference, symbol attribute and error listing.
- Compiler controls and directives are compatible with other Intel language translators.
- Optional Reentrancy.
- User-defined default storage lengths.
- Optional FORTRAN 66 Do Loop semantics.
- Source files may be prepared in free format.
- The INCLUDE control permits specified source files to be combined into a compilation unit at compile time.
- Transparent interface for software and hardware floating point support, allowing either to be chosen at time of linking.

FORTRAN-80 BENEFITS

FORTRAN-80 provides a means of developing application software for Intel® MCS-80/85 products in a familiar, widely accepted, and computer industry-standardized programming language. FORTRAN-80 will greatly enhance the user's ability to provide cost-effective solutions to software development for Intel microprocessors as illustrated by the following:

- *Completely Complementary to Existing Intel Software Design Tools* — Object modules are linkable with new or existing Assembly Language and PL/M Modules.
- *Incremental Runtime Library Support* — Runtime overhead is limited only to facilities required by the program.
- *Low Learning Effort* — FORTRAN-80, like PL/M, is easy to learn and use. Existing FORTRAN software can be ported to FORTRAN-80, and programs developed in FORTRAN-80 can be run on any other computer with ANS FORTRAN 77.
- *Earlier Project Completion* — Critical projects are completed earlier than otherwise possible because FORTRAN-80 will substantially increase programmer productivity, and is complementary to PL/M Modules by providing comprehensive arithmetic, I/O formatting, and data management support in the language.
- *Lower Development Cost* — Increases in programmer productivity translates into lower software development costs because less programming resources are required for a given function.
- *Increased Reliability* — The nature of high-level languages, including FORTAN-80, is that they lend themselves to simple statements of the program algorithm. This substantially reduces the risk of costly errors in systems that have already reached production status.
- *Easier Enhancements and Maintenance* — Like PL/M, program modules written in FORTRAN-80 are easier to read and understand than assembly language. This means it is easier to enhance and maintain FORTRAN-80 programs as system capabilities expand and future products are developed.
- *Comprehensive, Yet Simple Project Development* — The Intellec Microcomputer Development System, with the 8080/8085 Macro Assembler, PL/M-80 and FORTRAN-80 is the most comprehensive software design facility available for the Intel MCS-80/85 Microprocessor family. This reduces development time and cost because expensive (and remote) timesharing or large computers are not required.

SAMPLE FORTRAN-80 SOURCE PROGRAM LISTING

```
*    **  THIS PROGRAM IS AN EXAMPLE OF ISIS-II FORTRAN-80 THAT
*    **  CONVERTS TEMPERATURE BETWEEN CELSIUS AND FARENHEIT

      PROGRAM CONVRT

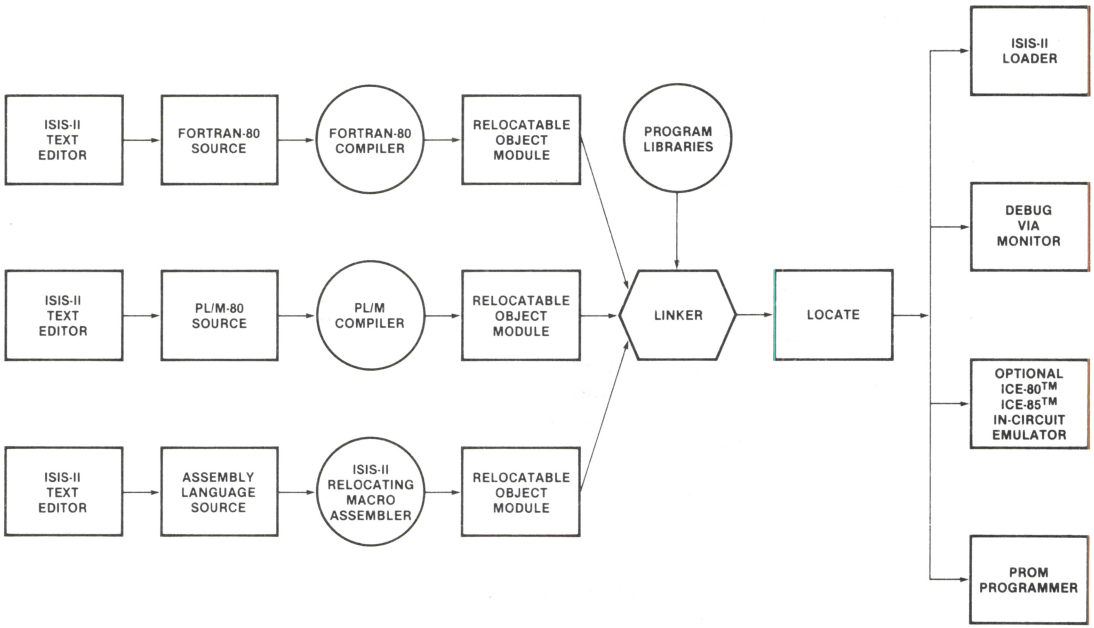
      CHARACTER*1 CHOICE, SCALE

      PRINT 100
*     **  ENTER CONVERSION SCALE (C OR F)
10    PRINT 200
      READ (5,300) SCALE

        IF (SCALE .EQ. 'C')
     +     THEN
              PRINT 400
*             **  ENTER THE NUMBER OF DEGREES FARENHEIT
              READ (5,*) DEGF
              DEGC = 5./9.*(DEGF-32)
*             **  PRINT THE ANSWER
              WRITE (6,500) DEGF,DEGC
*             **  RUN AGAIN?
20            PRINT 600
              READ (5,300) CHOICE
                 IF (CHOICE .EQ. 'Y')
     +              THEN
                       GOTO 10
                 ELSE IF (CHOICE .EQ. 'N')
     +              THEN
                       CALL EXIT
                 ELSE
                    GOTO 20
                 END IF
        ELSE IF (SCALE .EQ. 'F')
     +     THEN
*             **  CONVERT FROM FARENHEIT TO CELSIUS
              PRINT 700
              READ (5,*) DEGC
              DEGF = 9./5.*DEGC+32.
*             **  PRINT THE ANSWER
              WRITE (6,800) DEGC,DEGF
              GOTO 20
        ELSE
*          **  NOT A VALID ENTRY FOR THE SCALE
           WRITE (6,900) SCALE
           GOTO 10
        END IF
100   FORMAT(' TEMPERATURE CONVERSION PROGRAM',//,
     +' TYPE C FOR FARENHEIT TO CELSIUS OR',/,
     +' TYPE F FOR CELSIUS TO FARENHEIT',//)
200   FORMAT(/,' CONVERSION? ',$)
300   FORMAT(A1)
400   FORMAT(/,'ENTER DEGREES FARENHEIT: ',$)
500   FORMAT(/,F7.2,  DEGREES FARENHEIT = ',F7.2,' DEGREES CELSIUS')
600   FORMAT(/,' AGAIN (Y OR N)? ',$)
700   FORMAT(/,' ENTER DEGREES CELSIUS: ',$)
800   FORMAT(/,F7.2,' DEGREES CELSIUS = ',F7.2,' DEGREES FARENHEIT',/)
900   FORMAT(/,1H ,A1,' NOT A VALID CHOICE - TRY AGAIN!',/)
      END
```

FORTRAN-80

The FORTRAN-80 Compiler is an efficient, multiphase compiler that accepts source programs, translates them into relocatable object code, and produces requested listings. After compilation, the object program may be linked to other modules, located to a specific area of memory, then executed. The diagram shown below illustrates a program development cycle where the program consists of modules created by FORTRAN-80, PL/M-80 and the 8080/8085 Macro Assembler.



SPECIFICATIONS

OPERATING ENVIRONMENT

Required Hardware:

Intellec® Microcomputer Development System
- — MDS-800, MDS-888
- — Series II Model 220, Model 230

64K bytes of RAM memory

Dual diskette drives
- — Single or Double Density

System console
- — CRT or hardcopy interactive device

Optional Hardware:

Line Printer
ICE-80™, ICE-85™

Required Software:

ISIS-II Diskette Operating System
- — Single or Double Density

Optional Software:

iSBC-801 FORTRAN-80 Run-Time Software Package for RMX-80

DOCUMENTATION PACKAGE

FORTRAN-80 Programming Manual (9800481)

ISIS-II FORTRAN-80 Compiler Operator's Manual (9800480)

FORTRAN-80 Programming Reference Card (9800547)

SHIPPING MEDIA

Flexible Diskettes
- — Single and Double Density

ORDERING INFORMATION

PRODUCT CODE	DESCRIPTION
MDS-301	FORTRAN-80 Compiler for Intellec Microcomputer Development Systems

BASIC-80
EXTENDED ANS 1978 BASIC
INTELLEC® RESIDENT INTERPRETER

Meets ANS 1978 standard for minimal BASIC and adds many powerful extensions

Operates under the ISIS-II operating system on Intellec and Intellec® Series-II Microcomputer Development Systems

Full sequential and random disk file I/O with ISIS-II

Applications range from prototyping microcomputer software to inexpensive engineering and management problem solving on the Intellec® systems

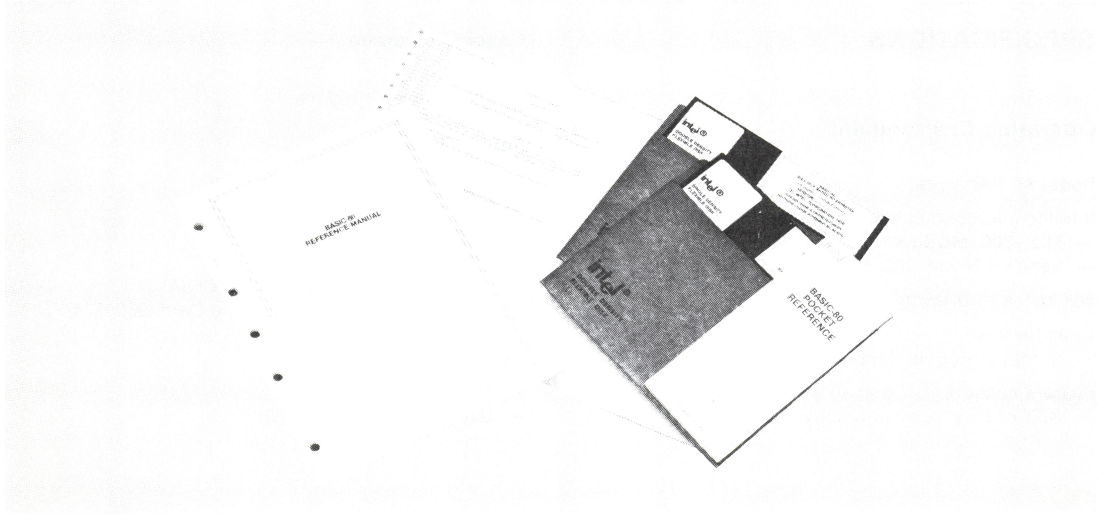
Supports the Intel floating point standard and provides integer and string data types

Can call user subroutines written in FORTRAN-80, PL/M-80, and 8080/85 macro assembler that are resident in the Intellec® memory

Easily learned language and interactive environment combine to provide a flexible and powerful facility for developing programs to run on the Intellec® Microcomputer Development Systems

BASIC is an industry standard, high-level programming language which is designed to be easily learned and used by novices and experienced programmers alike. The interpreter provides an interactive environment which allows fast and easy program development, testing, and debugging. BASIC is widely used for problem solving in engineering and management; extensive software exists for business applications such as order entry, accounts receivable, accounts payable, and inventory control, and engineering applications such as numeric and statistical analysis.

Intel's BASIC-80 meets the standards of ANS 1978 BASIC and extends them to take advantage of the software development capabilities of the Intellec Microcomputer Development Systems. The matching of these resources with the ease of programming in BASIC-80 provides a very effective tool for both microprocessor systems development and inexpensive applications programming and problem solving on the Intellec systems.



BASIC-80 LANGUAGE FEATURES

Standard ANS 78 BASIC features, all supported by BASIC-80, include:

- String and numeric constants, variables, and arrays.
- FOR . . . TO . . . STEP . . . NEXT statements for loop execution.
- IF . . . THEN statements for conditional execution.
- ON . . . GOTO statements for computed branching.
- GOSUB/RETURN subroutine calls and returns.
- Built in scientific functions:

ABS	RND	TAN
EXP	SGN	COS
INT	SQR	SIN
LOG	ATN	

- User defined single statement functions.

Major extensions to ANS 78 BASIC which BASIC-80 provides include:

- Support for the Intel single and double precision floating point standard.
- Disk file I/O, supporting both random access and sequential access files.
- Direct read and write to CPU I/O ports through the INP and OUT functions.
- Direct memory read and write through the PEEK and POKE functions.
- Calls to user-supplied external subroutines, which may have been written in FORTRAN-80, PL/M-80, or 8080/8085 Assembly Language and have been located at absolute memory locations using the ISIS-II facilities.
- User directed error trapping and handling functions.
- Program execution trace command.
- Formatted print statement with the PRINT USING function.
- ELSE clause for IF . . . THEN statements.
- Matrices with up to 110 dimensions.
- Extensive string manipulation functions.
- Boolean operators.
- Type conversion functions—integer, floating point, and character.

BENEFITS OF BASIC-80

- Added Value to the Intellec Systems—with BASIC-80 the Intellec Microcomputer Development Systems can be effectively used in many engineering and management applications.
- Inexpensive and Accessible Computational Facility—the ease of use and flexibility inherent in BASIC-80 and its interpretive environment fit well with the "at hand" computational resources of the Intellec systems. The combination is a particularly useful tool for obtaining fast and accurate results.
- Easy to Learn—the language is designed to be easily understood and learned. Results are obtained faster and people who may benefit from using the system can do so easily.
- Aid in Microcomputer Software Design—microcomputer software can be prototyped in BASIC-80 to inexpensively develop and test program logic.
- Complemented by Existing Software—subroutines written in PL/M-80, FORTRAN-80, and ASM 8080/85 can be called from BASIC-80 programs.
- Easy to Enhance and Maintain—BASIC-80, being straightforward and easily understood, provides for programs that are easy to maintain and modify in the future.

SPECIFICATIONS

Operating Environment

Required Hardware:

Intellec Microcomputer Development System
— MDS-800, MDS-888
— Series-II Model 220, Model 230

48K bytes of RAM memory

Diskette drive
— Single or double density

System console
— CRT or hard copy interactive device

Optional Hardware:

Line printer
Additional diskette drive

Required Software:

ISIS-II Diskette Operating System
— Single or double density

Documentation Package:

Basic-80 Reference Manual (9800758A)
Basic-80 Programming Reference Card (9800774)

Shipping Media:

Flexible diskettes
— Single and double density

EXAMPLE BASIC-80 PROGRAM

```
list
10 PRINT "THIS PROGRAM CALCULATES THE MEAN AND STANDARD"
20 PRINT " DEVIATION OF INPUT DATA"
30 S=0:V=0
40 INPUT "NUMBER OF VALUES";N
50 FOR I=1 TO N
60 INPUT A(I)
70 S=S+A(I)
80 NEXT
90 S=S/N
100 REM CALCULATION OF VARIANCE
110 FOR I=1 TO N
120 V=V+(A(I)-S)^2/N
130 NEXT
140 SD=SQR(V)
150 PRINT "MEAN=";S
160 PRINT "STANDARD DEVIATION IS=";SD
Ok


run
THIS PROGRAM CALCULATES THE MEAN AND STANDARD
 DEVIATION OF INPUT DATA
NUMBER OF VALUES? 6
? 34.7
? 32.9
? 38.2
? 35
? 37.6
? 40.9
MEAN= 36.55
STANDARD DEVIATION IS= 2.642442
Ok
```

ORDERING INFORMATION

Product Code	Description
MDS-320	ISIS-II BASIC-80 Disk-Based Interpreter

iCIS-COBOL™ SOFTWARE PACKAGE

Meets and exceeds minimum ANSI Level 1 standard for COBOL (X3.23-1974).

Runs under ISIS-II on Intellec or Intellec® Series II Microcomputer Development Systems.

Compiler compiles COBOL source programs into an intermediate code which is optimized for speed and memory space.

Includes execution run-time interpreter and an interactive debugger.

Powerful extensions for interactive programming.

Can Link/Call routines written in PL/M-80, FORTRAN-80 and 8080/8085 Assembly Language.

FORMS utility program allows the user to design and test CRT screen format input by generating COBOL source code for the data descriptions defining that CRT screen format.

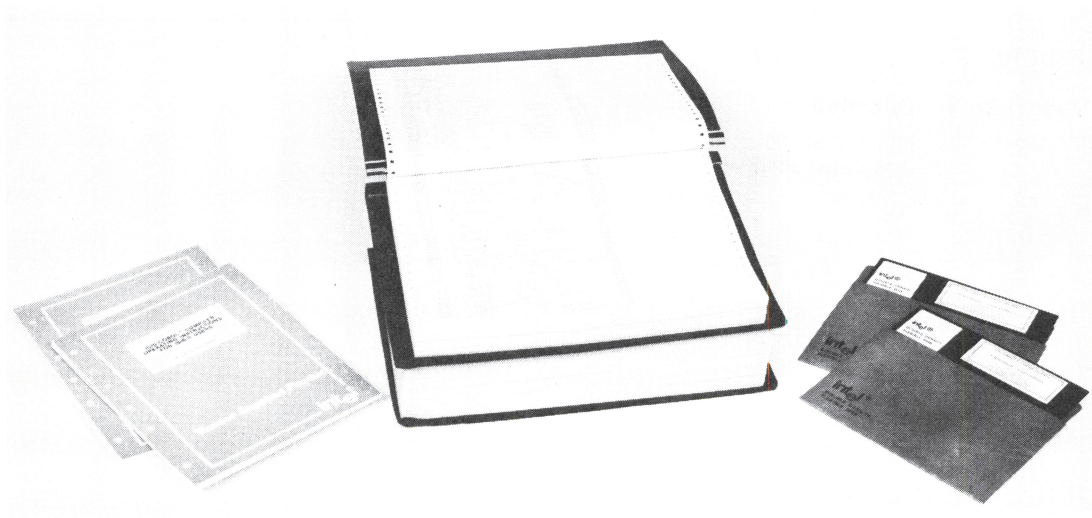
Compile-time option available to flag any non-ANSI standard features for portability.

Tested using U.S. Dept. of Navy COBOL validation system.

iCIS-COBOL, an acronym for Intel's Compact Interactive Standard COBOL, is a package designed to provide a powerful interactive business language to users of Intel's Intellec and Intellec Series II Microcomputer Development Systems. iCIS-COBOL contains the most relevant parts of the ANSI 74 standard plus extra extensions to make this product especially useful to Intellec users. The compiler provides a feature to optionally disallow the iCIS-COBOL extensions and rigidly enforce the ANSI 74 specification. This will prove beneficial to users who may need to port COBOL programs from the Intellec system to any other ANS Level 1 COBOL compiler.

iCIS-COBOL Compiler generates object code for a COBOL "virtual machine." This code is designed for optimum representation of COBOL verbs and data types. The code generated is interpreted by a Run-Time System. This consists of an interpreter which emulates the COBOL virtual machine and interfaces to the ISIS-II operating system and the CRT.

After an application program has been tested and is ready for production use, it is possible to link it permanently to the Run-Time System to form a free-standing ISIS-II loadable program.



LANGUAGE FEATURES

COBOL consists of twelve different modules implemented either to Level 1 or Level 2 as defined in the ANSI specification X3.23. iCIS-COBOL includes the following modules implemented to Level 1:

Nucleus
Table Handling
Sequential I/O
Relative I/O
Indexed I/O
Library
Interprogram Communication

Extensions to ANSI Specification:

- *Advanced screen formatting and data entry facilities.* These include protected and unprotected data, cursor manipulation, and numeric vet.
- *Run time input of filenames.* The actual value of the external filename may be moved to a file identifier location prior to OPENing the file, avoiding the need for an external linking mechanism.
- *Line sequential files.* Variable length records separated by carriage return/line feed saves space on disk and allows iCIS-COBOL programs to process files output by a text editor.
- *Hexadecimal literals.* These may be used to define control characters to output to special peripheral devices.
- *Rapid development facilities.* During development, compiled programs may be loaded directly by the Run-Time System "fast load" facility, thus avoiding the time otherwise spent in linking.
- *Interactive debugging.* Interactive debugging permits the setting of breakpoints, examination and modification of store, etc., at run time. Each COBOL statement is identified by a four-digit hexadecimal number.
- *Lower case.* This is permitted in COBOL words and comments, thus helping to produce easy to read documentation in the program.

INTERACTIVE CRT HANDLING

Intel has taken COBOL — traditionally a batch processing language — and extended it to become interactive. iCIS-COBOL offers many facilities for automatically formatting a CRT screen and facilitating input keying.

The user can format the screen of any system console (CRT) into protected and unprotected fields by using standard COBOL statements. The screen layout may be defined in the DATA DIVISION. An ACCEPT statement nominates a record description which permits input to the character positions corresponding to variables identified by data-names. These may be separated by FILLERs to position them on the screen. Conversely, a DISPLAY outputs only from non-FILLER fields in the record description which it nominates. The programmer can easily build up complex conversations for data entry and transaction processing.

When data is being keyed in, the operator has full cursor manipulation facilities, each variable acting as a tab stop. Non-numeric digits may not be keyed into fields defined as PIC 9. Finally, when the operator has checked that the data is correct, the RETURN key is pressed and processing continues.

SCREEN LAYOUT AND FORMAT FACILITIES	CURSOR CONTROL FACILITIES
Screen as a record description	HOME to the start of the first data field on the screen
FILLER	→ Forward space
REDEFINES	← Backward space
AT line:column	↓ Forward field
Character highlighting	↑ Backward field
Clear screen	C/R Release the screen of data
Numeric vet for PIC fields	L/F Left Fill numeric field
	(The actual keys used vary according to CRT keyboard)

FORMS UTILITY

A majority (up to 80%) of debugging time can be spent in designing, coding and testing the screen form input/output of a COBOL program. The FORMS utility included in the iCIS-COBOL package significantly reduces this debugging time.

Using the FORMS program, the user may:

- Store an image copy on disk of the form he has defined for subsequent use.
- Generate iCIS-COBOL source code for the data descriptions required to define the form just created. This may then be included in an iCIS-COBOL program using COPY.
- Choose to generate a checkout program which allows duplication of the many machine conversations which would take place during a run of the application which is being designed.

COMPILE TIME DIRECTIVES

- ANS

  If specified, the Compiler will accept only those iCIS-COBOL language statements that conform to the ANS 74 standard.

- RESEQ

  If specified, the Compiler generates COBOL sequence numbers, renumbering each line in increments of 10.

- NOINT

  No intermediate code file is output. The Compiler is, in effect, used for syntax checking only.

- NOLIST

  No list file is produced; used for fast compilation of "clean" programs.

- COPYLIST

  The contents of the file(s) nominated in COPY statements are listed.

- NOFORM

  No form feed or page headings are to be output by the Compiler in the list file.

- ERRLIST

  The listing is limited to those COBOL lines containing syntax errors together with the associated error message(s).

- INT (external-file-name)

  Specifies the file to which the intermediate code is to be directed.

- LIST (external-file-name)

  Specifies the file to which the listing is to be directed.

- FORM (integer)

  Specifies the number of COBOL lines per page of listing.

- NOECHO

  Error lines are echoed on the console unless this directive is specified.

BENEFITS

- Brings COBOL to Intellec Microcomputer Development Systems.
  - — COBOL is the industry standard high-level language for business-oriented applications.
  - — Most COBOL programs are self-documenting.
  - — Conversational verbs and phrases and common business terminology make COBOL easy to learn, use and maintain.
  - — More business and application programs are written in COBOL than any other language.
- Meets and exceeds ANS Level 1 COBOL standard.
  - — Assures portability to and from all computers supporting ANS Level 1 COBOL.
  - — Extensive testing and validation using U.S. NAVY COBOL VALIDATION SYSTEM assures functionality for all Level 1 features.
- iCIS-COBOL software package provides an easy to use, efficient and friendly environment for COBOL program development.
  - — CONFIGURATOR program allows the user to reconfigure the software for any non-standard, non-Intel CRT.
  - — Interactive debugger provides features aimed at a CRT based system (rather than batch-oriented).
  - — FORMS utility program reduces total program development time by 30%.
  - — All iCIS-COBOL utilities make use of CRT cursor control.
- Adds value to an Intellec development system.
  - — COBOL applications programs developed using iCIS-COBOL software package will increase utilization of Intellec development systems.

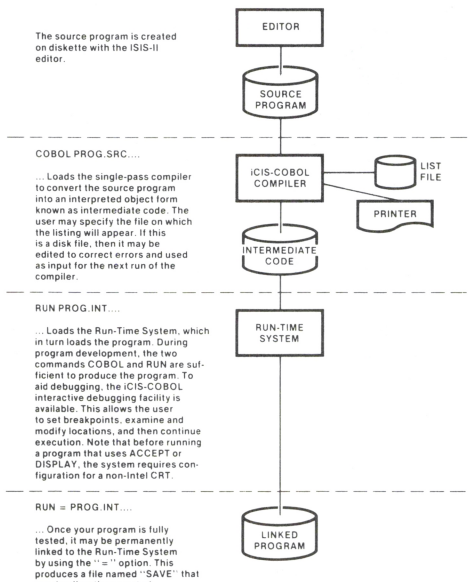


Figure 7-12. Program Development Cycle

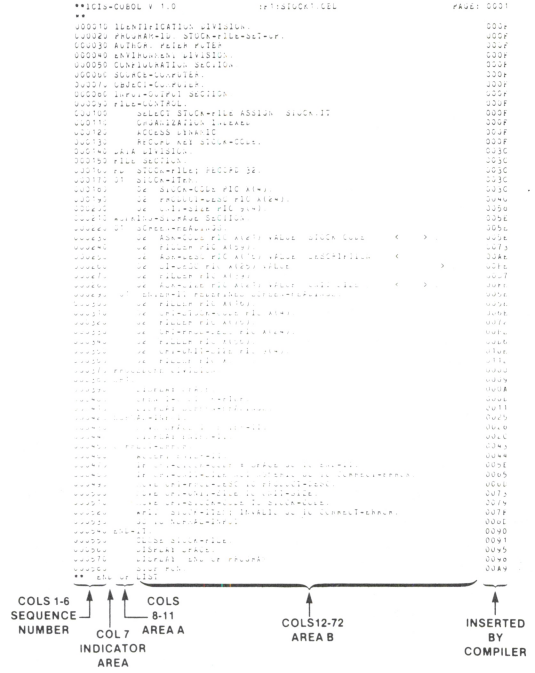


Figure 7-13. Sample Program Listing Showing Source Format

SPECIFICATIONS

Operating Environment

Required Hardware:

Intellec Microcomputer Development System
— Model 800
— Series II Model 220, Model 230

48KB of Memory

Dual Diskette Drives
— Single or Double Density

System Console
— Intel or non-Intel CRT

Recommended Hardware:

64KB of Memory

Double Density Dual Diskette Drives

Optional Hardware:

Line Printer

Required Software:

ISIS-II Diskette Operating System
— Single or Double Density

Optional Software:

ISIS-II CREDIT (CRT-Based Text Editor)

Documentation Package

iCIS-COBOL Language Reference Manual (9800927-01)

iCIS-COBOL Compiler Operating Instructions for ISIS-II Users (9800928-01)

iCIS-COBOL Pocket Reference (9800929-01)

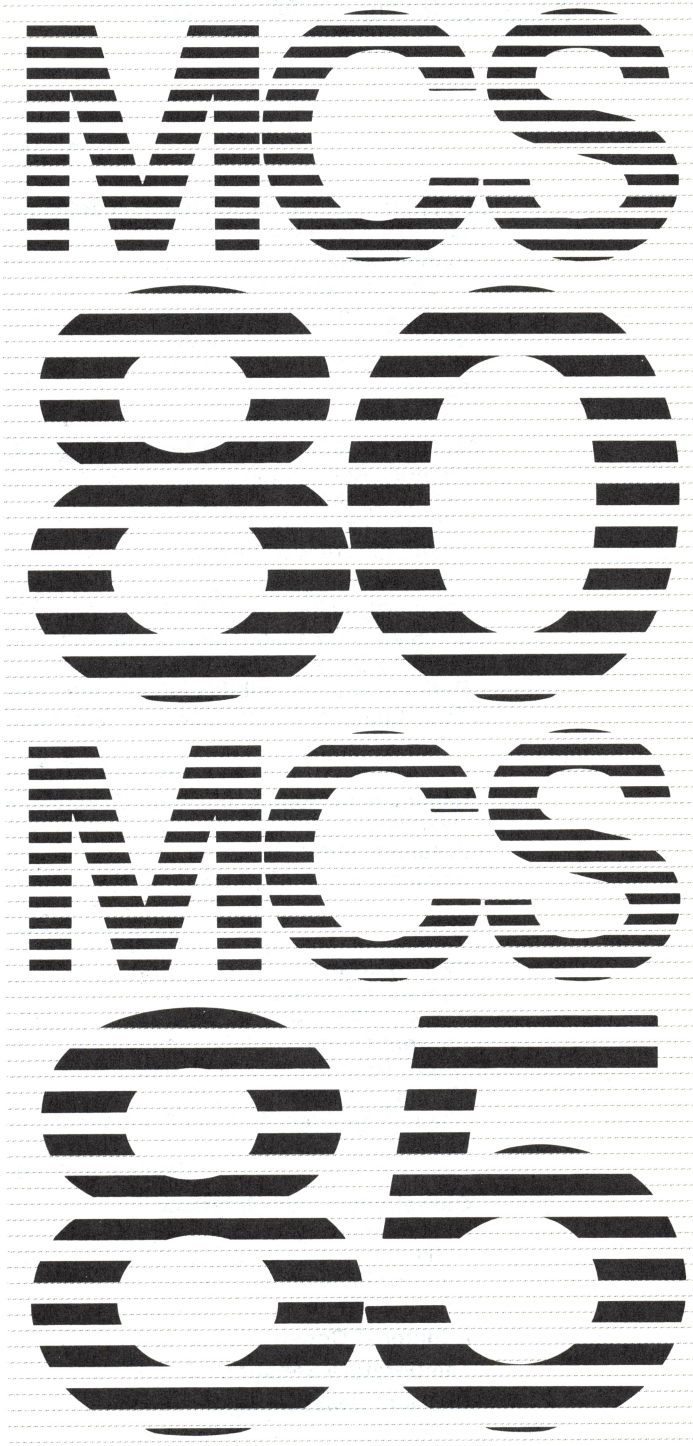
Shipping Media

Flexible Diskettes
— Single and Double Density

ORDERING INFORMATION:

Product Code	Description
MDS-380	iCIS-COBOL Software Package

Appendix
Applications
of MCS-85™



Appendix
Applications of MCS-85™

Contents

SECTION 1 INTRODUCTION TO MCS-85™ APPLICATIONS

MCS-85™ System A1-1
Sample Applications A1-2
Baud Rate Generator A1-2
Serial Communications A1-2
Small System A1-6
Block Move, Block Search A1-6
RST 7 ..... A1-7

SECTION 2 DETAILED APPLICATION EXAMPLES

Memory Addressing A1-8
ROM, EPROM A1-8
Static Memories A1-11
Dynamic RAM Interface A1-11
System Timings A1-16
8085A CLK-IN vs. CLK-OUT vs. Control Timings A1-16
3.125 vs. 5 MHz Considerations A1-18
Memory Device Compatibility A1-20
Peripheral Compatibility—3.125 and 5 MHz A1-23
Bus - Loading Considerations - Decoupling A1-25

APPLICATION EXAMPLE 1

Minimum System Application Example as a Temperature Sensor A1-26
Overview A1-26
Detailed Hardware A1-26
Software Block Move, Search Illustrations A1-29

APPLICATION EXAMPLE 2

CRT Interface A1-32
Hardware Interface A1-32
Software Package A1-32
Output Routine A1-34
Input Routine A1-35
Timing Analysis A1-35
Baud Rate Identification Routine A1-36

APPLICATION EXAMPLE 3

Cassette Recorder Interface A1-38
Hardware Design A1-38
Software A1-38
Output Routine A1-40
Input Routine A1-40
Additional Comments A1-42
Temperature Sensor Code A1-44
CRT and Cassette Code A1-48

APPENDIX 1
APPLICATIONS OF MCS-85™

SECTION 1
INTRODUCTION TO MCS-85™ APPLICATIONS

When the first microprocessor was introduced about five years ago, it was largely ignored by the electronics industry. However, since that inasupicious beginning, this new device has become the hottest topic in current technology. As more and more product designers become familiar with the capabilities of microcomputers, the number of new applications increases geometrically. In most of these applications, the new technology has been used to replace designs which were formerly implemented with TTL logic and under-utilized minicomputers. However, an increasing number of products are surfacing which would have been impractical prior to the microcomputer era.

Microcomputers are being applied to a wide range of data communications tasks. The field of telephone equipment is being invaded by systems which control and monitor calls. Point of sale terminals are increasing daily with the addition of interface to coin changers, electronic scales and remote computers. Small stand-alone computers are relying heavily upon microcomputers in teleprocessing, time-sharing, data base management and similar interactive applications. An increasing number of microcomputer-based data terminals are providing local interactive intelligence with programmable character sets, vector generation and the pre-processing of data.

Instrumentation is widely utilizing the microprocessor for a variety of control and arithmetic processing functions. Microcomputers are controlling laboratory equipment such as oscilloscopes, DVM's, network analyzers and frequency synthesizers. Medical electronics are crediting microcomputers with tasks such as patient monitoring, blood analysis and X-ray scanning. Travel is becoming microcomputerized by automotive control, air and ocean navigation equipment and rapid transit systems.

MCS-85™ SYSTEM

Many possible microcomputer applications have been overlooked because of the design tasks required to build the microcomputer. These tasks include the system clock, read/write memory, I/O ports, serial communications interface and bus control logic. The MCS-85 system will enable the design engineer to concentrate on the application of the microcomputer, rather than on the implementation details.

The MCS-85 is yet another family of components which has the potential to provide a solution to the three problems which will always plague designers: cost, size and power. The reduced component count of an MCS-85 microcomputer, coupled with the increased integration of functions reduces both cost and size while increasing power.

Sample Applications

Calculating Oscilloscope
Blood Analyzer
Programmable Video Game
Process Control System
Line Printer
Intelligent Terminal
N.C. Machine
Digital Multimeter
Graphic Terminal
Automotive Control
Navigation Equipment
Vending Machine
Spectrum Analyzer
Front End Processor
Credit Verifier
Disk Controller
Patient Monitor
Network Analyzer
Frequency Synthesizer

APPLICATION	PERIPHERAL DEVICES ENCOUNTERED	MCS-85™ COMPONENTS	
Intelligent Terminals	Cathode Ray Tube Display	8275	8085A
	Printing Units	8155	8355
	Synchronous and Asynchronous data lines	8251	
	Cassette Tape Unit		
	Keyboards	8279	
Gaming Machines	Keyboards, pushbuttons and switches	8279	8085A
	Various display devices		8355
	Coin acceptors	8155	
	Coin dispensers		
Cash Registers	Keyboard or Input Switch Array	8279	8085A
	Change Dispenser	8155	8355
	Digital Display		
	Ticket Printer		
	Magnetic Card reader		
	Communication interface	8273	
Accounting and Billing Machines	Keyboard	8279	8085A
	Printer Unit	8155	8355
	Cassette or other magnetic tape unit	8257	
	"Floppy" disks	8271	
Telephone Switching Control	Telephone Line Scanner	8253	8085A
	Analog Switching Network		8355
	Dial Registers	8155	
	Class of Service Parcel		
Numerically Controlled Machines	Magnetic or Paper Tape Reader	8155	8085A
	Stepper Motors		8355
	Optical Shaft Encoders		
Process Control	Analog-to-Digital Converters	8155	8085A
	Digital-to-Analog Converters		8355
	Control Switches	8279	
	Displays		

Baud Rate Generator

Shown in Figure 2 is a minimum system configuration with the 8156 timer output connected to an 8085 interrupt input.

This configuration allows convenient use of the timer as a baud rate generator. A 6.144 MHz crystal is used as the frequency control element of the 8085A, providing integral divisors for the standard baud rates (300, 600, 1200, 2400, 4800, 9600 baud). The timer is programmed with the appropriate divisor (Figure 1) for the selected baud rate resulting in one pulse on the timer output for each bit cell time. The clock output (CLK) of the 8085A is used to clock the timer (TIMERIN). The frequency of this clock is one-half the crystal frequency or in this example 3.072 MHz. $\overline{\text{TIMEROUT}}$ now provides a crystal controlled pulse train at the baud rate selected.

Serial Communications

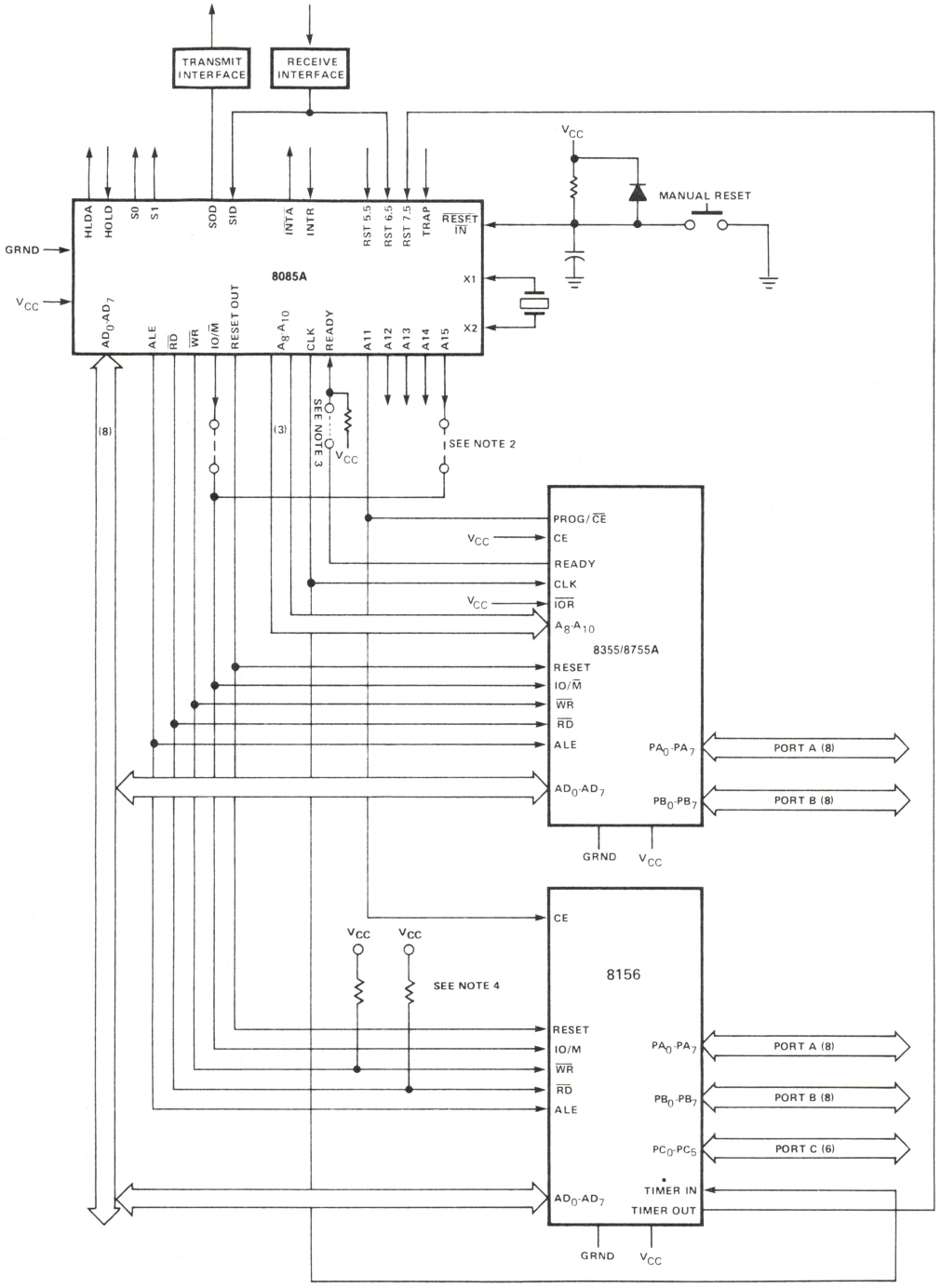
By feeding the $\overline{\text{TIMEROUT}}$ signal of the 8156 back to the edge triggered RST 7.5 input of the 8085A, the processor can be interrupt driven at the required baud rate. As shown in Figure 1, the minimum system supports serial communications with only the addition of the send and receive interface circuits.

The SID (SERIAL INPUT DATA) line and the SOD (SERIAL OUTPUT DATA) line are connected directly to a TTY or RS232 interface circuit. Assuming inverted data at the SID input, a direct connection is made to the RST6.5 input for detection of the start bit.

Additional insight into using the 8085's serial I/O lines in communications application can be found in Section 2 of this Appendix.

BAUD RATE	COUNT (DECIMAL)
300	10,240
600	5,120
1200	2,560
2400	1,280
4800	640
9600	320

FIGURE 1. BAUD RATES



NOTE 1: TRAP, INTR, AND HOLD MUST BE GROUNDED IF THEY AREN'T USED.
NOTE 2: USE IO/M FOR STANDARD I/O MAPPING. USE A15 FOR MEMORY MAPPED I/O.
NOTE 3. CONNECTION IS NECESSARY ONLY IF ONE T_{WAIT} STATE IS DESIRED.
NOTE 4: PULL-UP RESISTORS RECOMMENDED TO AVOID SPURIOUS SELECTION WHEN $\overline{RD}$ AND $\overline{WR}$ ARE 3-STATED.

FIGURE 2. MINIMUM SYSTEM CONFIGURATION

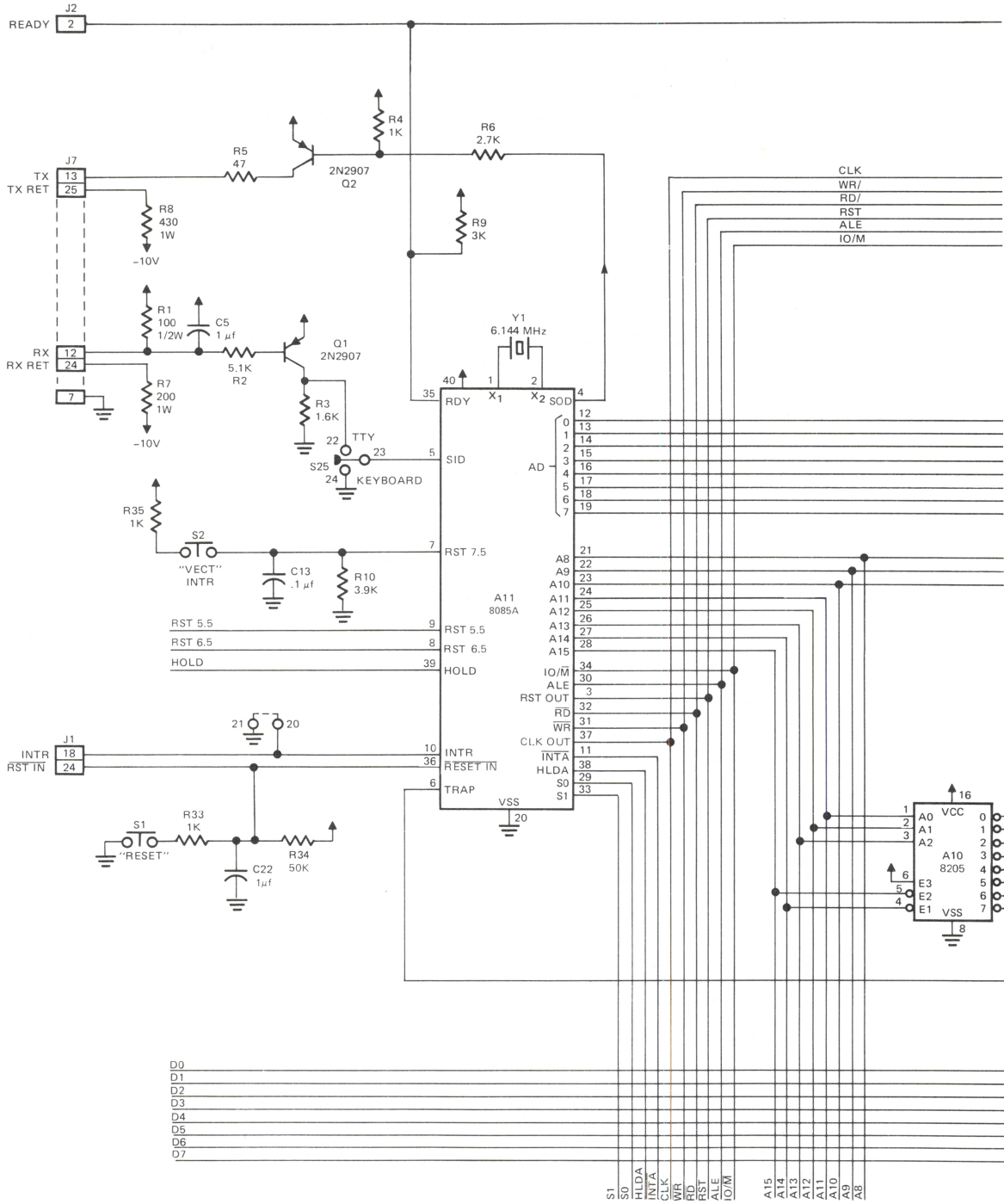
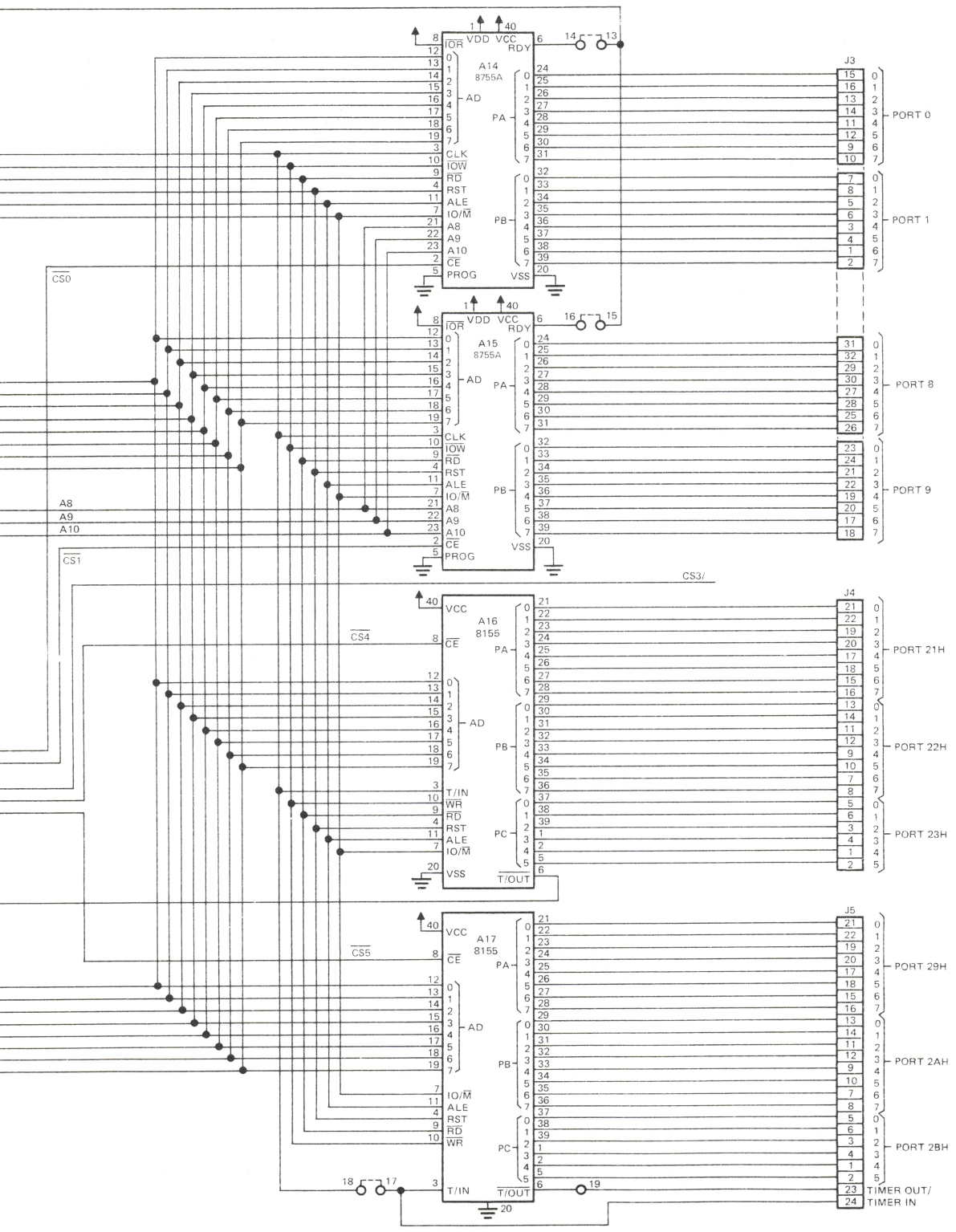


FIGURE 3. SMALL SYSTEM SCHEMATIC (similar to the schematic of Intel's SDK-85)


A14
8755A
A15
8755A
A16
8155
A17
8155
VDD
VCC
RDY
IOR
AD
PA
PB
CLK
IOW
RD
RST
ALE
IO/M
A8
A9
A10
CE
PROG
VSS
CS0
CS1
CS3/
CS4
CS5
T/IN
WR
PC
T/OUT
J3
J4
J5
PORT 0
PORT 1
PORT 8
PORT 9
PORT 21H
PORT 22H
PORT 23H
PORT 29H
PORT 2AH
PORT 2BH
TIMER OUT/
TIMER IN

Small System

The schematic in Figure 3 is of a complete microcomputer with only 6 ICs. The system contains its own serial I/O communication lines, multi-level interrupt, two programmable timers, and power-on reset. System capacity is 512 bytes of RAM, 4K bytes of PROM, and 76 lines of programmable I/O.

Block Move, Block Search

In a large system application high speed block moves may be necessary. The addition of an 8257 Direct Memory Access (DMA) controller and an 8255 Programmable Peripheral Interface (PPI) device with some miscellaneous logic removes the task from the 8085 and results in a very high speed capability. The addition of an eight bit comparator also permits block searches. (See Figure 4.)

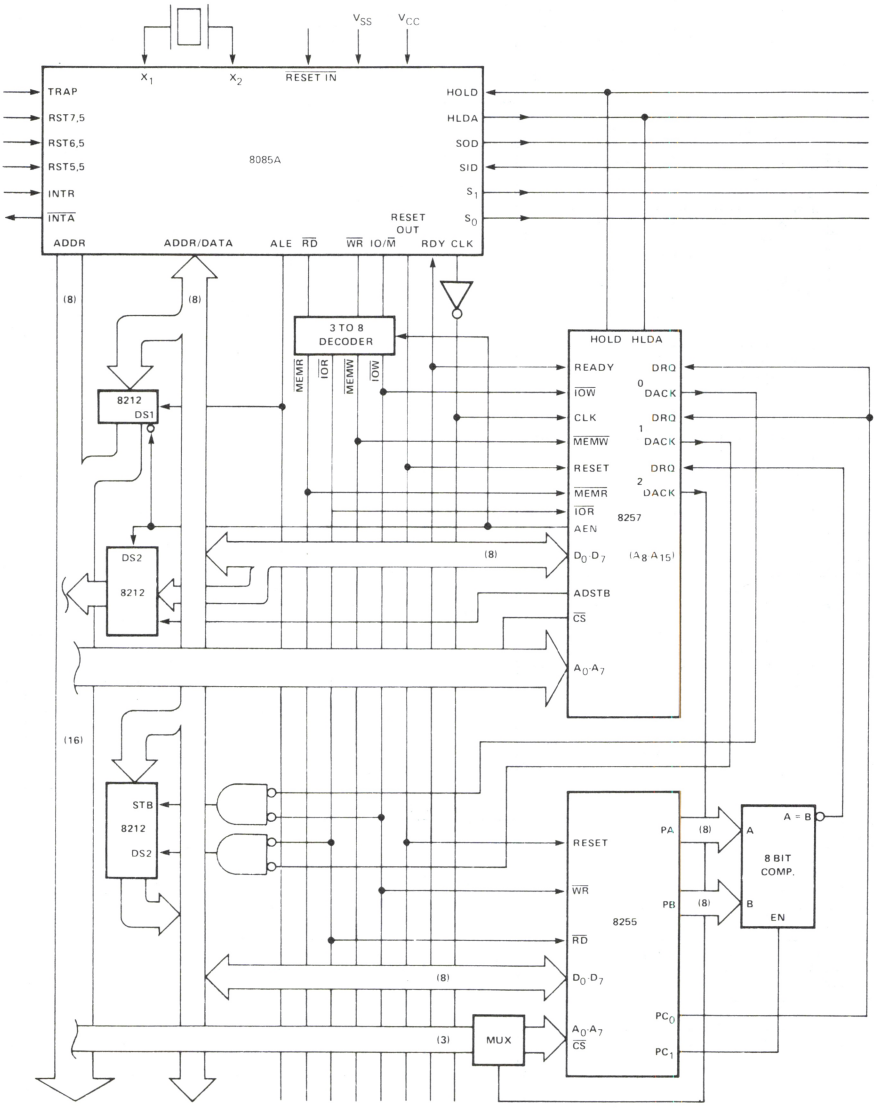


FIGURE 4. BLOCK MOVE, BLOCK SEARCH addition of an 8257 Direct Memory Access (DMA) controller and an 8255 Programmable Peripheral Interface (PPI) device permits block searches, high speed block moves. (2.5 μs/word).

Basic operation, for a block move, is that the CPU loads the 8257 with the starting address of the source block and the length* of the block into Channel 0. Channel 1 is programmed with the starting location of the destination block and the length. A bit in Port C of the 8255 is set by the CPU which initiates a DMA request on Channels 0 and 1. Because the 8257 is initialized to the rotating priority mode, the first DMA cycle is from Channel 0 which latches the data from the first location of the source block into the 8212. The second cycle will be from Channel 1 which will store the latched data into the first location of the destination block. The next cycle will return to Channel 0 and the sequence will start over again until the length (terminal count) is reached. Programming the 8257 stop bit insures that each channel will be disabled when its respective terminal count is reached.

This configuration also supports a block fill. DMA Channel 0 points to a location containing the fill value and has a length of one. Channel 1 points to the starting location of the destination block and contains the length. When the sequence is initiated the value will be loaded into the latch by Channel 0. Channel 0 reaches TC and is disabled. Priority rotates to Channel 1 which will repeatedly write into the destination block the value stored in the latch until TC is reached.

Block search operations use the 8-bit comparator and Ports A & B of the 8255 and Channel 2 of the 8257. The CPU loads Port B with the search value and the DMA channel with the search area (starting address and length). A Port C bit initiates the DMA READ request. Channel 2 DMA Acknowledge sets Port A of the 8255 up as the receiver for the DMA READ cycle by multiplexing A_0, A_1, and CS. Each cycle of the DMA then loads Port A with the value of the pointed-to location in the block. When Port A equals Port B, the output of the comparator will gate off the DMA request. The requesting program can now read the Channel 2 address which is pointing to the search value plus one. However, if the status register of the 8257 indicates that TC of Channel 2 has been reached, then no match was found.

*(The value loaded into the low-order 14-bits of the terminal count register specifies the number of DMA cycles minus one before the Terminal Count (TC) output is activated. For instance, a terminal count of 0 would cause the TC output to be active in the first DMA cycle for that channel. In general, if Length = the number of desired DMA cycles, load the value Length-1 into the low-order 14-bits of the terminal count register.)

RST 7

On the 8080A/8228 system if one tied $\overline{INTA}$ out of the 8228 to + 12 volts through a 1KΩ resistor, the 8228 would generate a RST 7 instruction to the 8080A upon interrupt. This was a very inexpensive mechanism.

The 8085A has expanded this facility with the RST 5.5, 6.5, 7.5 inputs but is not compatible with the RST 7 generated by the 8228. (Figure 5) To maintain this compatibility it can be achieved by adding an 8212 which will force a RST 7 instruction into the bus upon interrupt acknowledge ($\overline{INTA}$). (Figure 6)

RESTART	VECTOR LOCATION
RST 7	38_{16}
RST 5.5	$2C_{16}$
RST 6.5	34_{16}
RST 7.5	$3C_{16}$
TRAP	24_{16}

FIGURE 5. ADDITIONAL 8085A INTERRUPTS

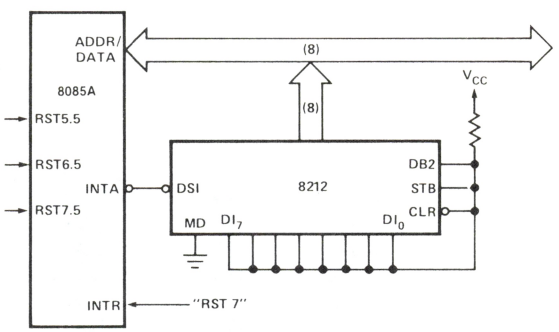


FIGURE 6. 8085A "RST 7" IMPLEMENTATION

SECTION 2
DETAILED APPLICATION EXAMPLES

Memory Addressing

One of the necessary functions of the microprocessor bus is to interface with the memory where the program is stored. ROM and EPROM memories are typically used to store programs while static and dynamic RAMS are generally used for data memory. The following discussions cover the interfacing to be used for these types of memory.

ROM - EPROM ADDRESSING

Later in this Appendix a section is devoted to an approach for developing a chart showing memory device compatibility for the 8085A. However, there is one area not included that will be discussed here, that is, unbuffered interfacing to standard ROM or EPROM memories. To use an unbuffered interface to ROM or EPROM it is necessary to understand a particular characteristic of the 8085A.

The 8085A has a period of time, T4 through T6 of the op code fetch cycle and certain instructions, where addresses A8 through A15 are undefined. Be careful about this. Not having addresses stable and using an address select method that would randomly turn on memory devices will cause bus contention and reliability problems in the unbuffered system. In the memory compatibility section of this Application Note, a minimum (unbuffered MCS-85 family and medium system (at least one level of buffering) configurations are considered. These configurations do not have bus contention problems. In the minimum system only MCS-85 components will be discussed where addresses are latched on the falling edge of ALE, thus ignoring any extraneous address transitions. The medium system is assumed to have data buffers that are enabled only at the proper time, thus again preventing any bus contention problems. What about the user who wants to use standard ROM or EPROM without buffering?

As an example let's look at Intel's ROM/EPROM family (Fig. 7) and develop a system block diagram. This system should allow upward compatibility for these particular devices and avoid any bus contentions due to undefined addresses. In Figure 8 a traditional decoding scheme is shown that uses the time difference between tacc (address access) and tco (chip select access) to allow for decoding of the EPROM/ROM to be selected. Connecting only these signals, however, in an unbuffered system will result in data contention because of the spurious addresses during opcode fetch. The proper interconnect for this type of interface is shown in Figure 9 where an output enable ($\overline{OE}$) signal will prevent any bus contention. This output enable is controlled by the read control signal, $\overline{RD}$, of the 8085A. This signal only occurs after addresses have stabilized.*

Note also that a PROM is recommended for the decoding function vs. an 8205 (1 of 8 decoder). Why? This PROM allows the user to easily upgrade his system to the 32 and 64K versions with minimum rewiring. As seen in Figure 3, only 4 pins are being altered (18-21) in the Intel ROM/EPROM family to allow for this upward compatibility. All a user would need to do is initially design his layout for 28 pin devices, thereby allowing total flexibility from 8K through 64K with the ease of only changing a decoding PROM and a few wires.† Application Note AP-30 can be ordered at no charge which fully discusses the application of Intel's 5 Volt EPROM and ROM family for microprocessor systems.

*Both $\overline{RD}$ and $\overline{WR}$ signals should be pulled up to +5V through a resistor to avoid random selection during 3-state.

†Another method is shown later in Figure 15 that facilitates the use of a decoder, such as the Intel 8205.

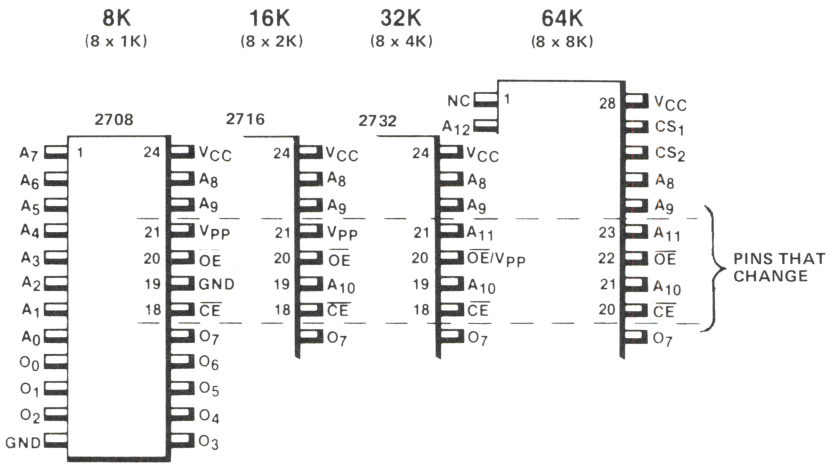


Figure 7. Intel® EPROM/ROM Compatible Family

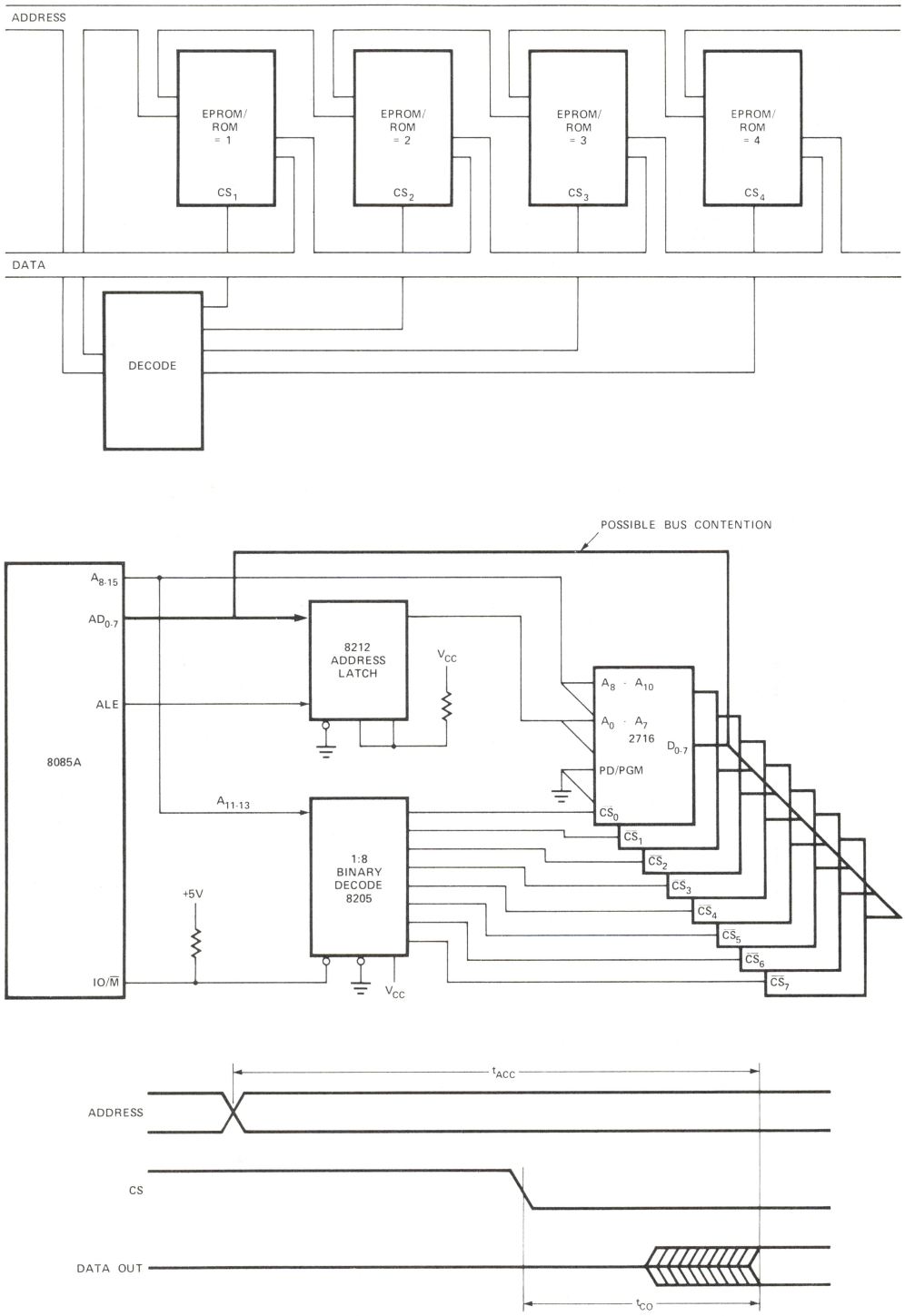


Figure 8. Traditional 16K EPROM System

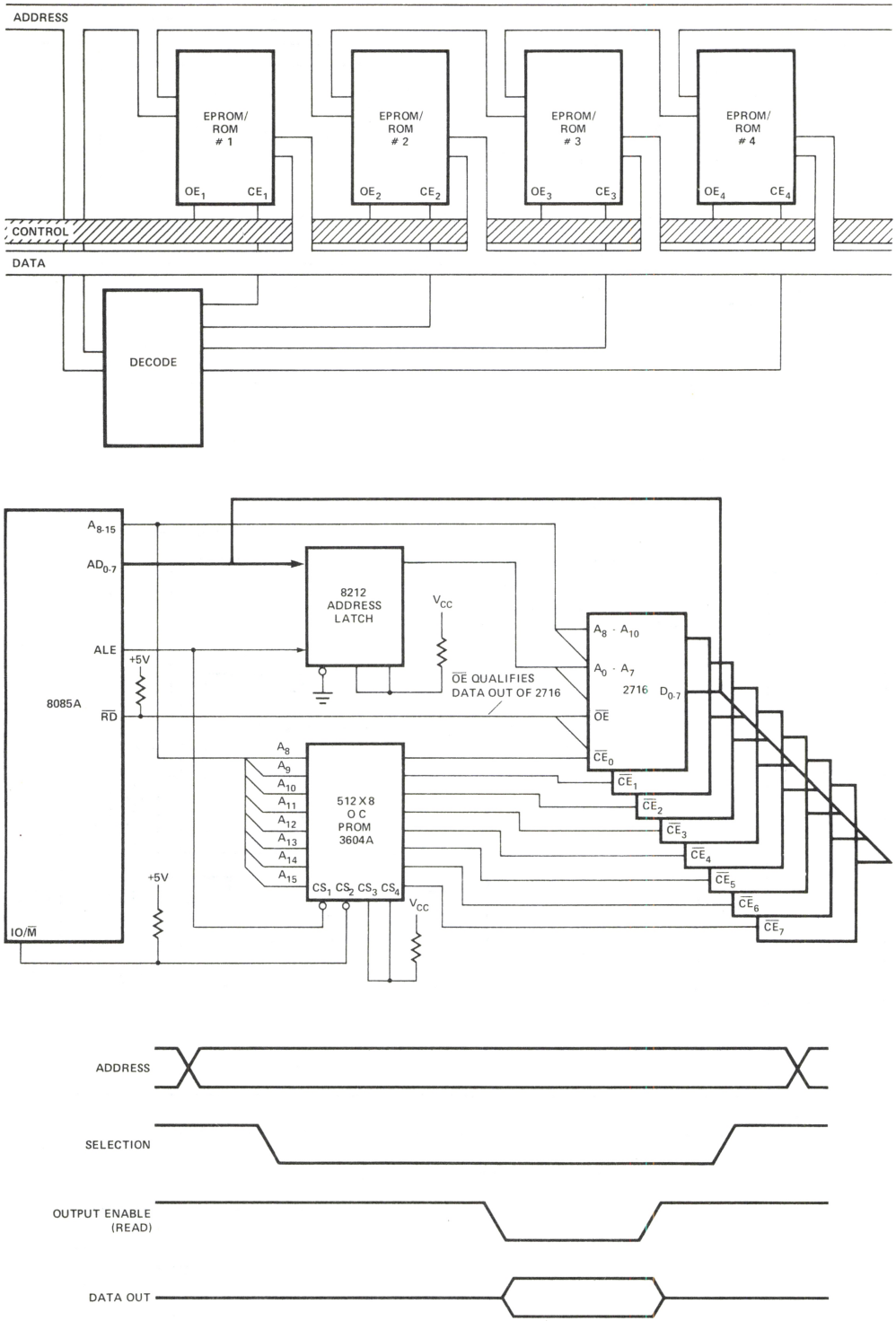


Figure 9. Correct 16K EPROM System

STATIC MEMORIES

The same consideration must be applied to standard static memories as with the ROMs/EPROMs in an unbuffered system. Memory device selection must be qualified by a memory read or write to prevent spurious selection. Some Intel static RAM devices have an Output Enable for this purpose, such as the 2142 (1k x 4). This part was designed to be specifically used with a microprocessor bus. For other standard static RAMs, the chip selects must be qualified by $\overline{RD}$, $\overline{WR}$ or ALE to prevent random selection.

DYNAMIC RAM INTERFACE

An earlier Intel Application Report (APR-1) extensively covered dynamic RAM interface with different types of memory and refresh in the MCS-80 system. This dynamic RAM section was taken from the most memory intensive example in APR-1, the 2116, modified to be compatible with the 8085A bus. These minor modifications are such that an 8080 system can be converted without much trouble. Before discussion of this section, however, a strong word of advice is in order. At about the same time this Application Note is published, Intel will be sampling an 8202 dynamic RAM refresh controller which does all dynamic RAM interfacing (except the data bus) and refreshing in *one* packaged component. It is highly recommended that the reader investigate this before using the attached schematic. Reading this section will still be useful in terms of understanding the 8085A bus.

This section uses the APR-1 2116 (multiplexed address 16K) example modified for the 2117-4 dynamic RAM. These devices have some differences from the 2116. One is that the output is not latched and is 3-stated during a write operation. This allows a user to tie both the data in and data out pins together at the device and at the data buffers, saving board traces. The 2117 also have hidden refresh capabilities where if $\overline{CAS}$ is held low, $\overline{RAS}$ can be toggled to refresh the device.

The schematic shown in Figure 10 is aimed at a high performance, relatively inexpensive solution (disregarding the 8202). Refresh circuitry is not shown, but can be implemented in a variety of ways. This will be discussed later in an upcoming section. In this refresh section, code for a simple, very low cost refresh controller that requires no special hardware, other than an 8155 timer, is presented.

For system timing, a 4x clock is used to obtain the resolution necessary to provide the clocks for the multiplexed address 2117's. Other solutions are possible with delay lines, one shots, etc., but are relatively expensive and don't provide for a nice baud rate source for any peripherals that may be in the system as does this 4x clock. Another approach can use the clock edges from the 8085A CLKOUT to interface to dynamic RAM. To facilitate this type of approach, Clock related timing parameters are listed later in this note.

To aid in understanding the operation of this circuit, the explanation is broken into a discussion of the main signal paths. 2117-4 Spec compatibility with the 8085A will be discussed in detail in the dynamic RAM section of the Memory Compatibility section.

Addresses

The lower 14 addresses (A0-A13) are used to select one of the 16,384 8-bit bytes in each 16K byte data bank. The lower 8 of these 14 addresses (A0-A7) flow through an 8212 and are latched by ALE, effectively demultiplexing the address/data bus. These lower 8 addresses with the next 6 (A8-A13) enter the 3242 multiplexer/refresh controller. The Row Enable of the 3242 controls which half of the addresses are presented to the dynamic RAM memory. Looking at the row enable on the 3242, it is seen that the row and column addresses are swapped with respect to convention. The higher order addresses are used as row addresses and the lower order addresses are used as column addresses. This does not create problems because this is invisible to the CPU. Refreshing is done properly as the 3242 controls the addressing for this. The upper two address lines (A_{14}-A_{15}) are decoded to qualify one of the four $\overline{RAS}$ (Row Address Strobe) lines to select one of the four 16K byte data banks of memory.

Cycle Requests

Cycle requests are generated from several sources; ALE automatically initiates a request when S1 indicates that there is a read taking place (flip-flop C), $\overline{WR}$ during write cycles (D) and refresh delayed (Q output of refresh flipflop (B)) when there is a refresh. ALE is used to start a read (qualified by S1) to provide ample time for access from the memories. This cycle request signal (A) immediately creates a $\overline{RAS}$ and starts a timing chain (74S174 shift register (E)) to generate the remaining signals. Synchronization between this cycle request pulse and the 4x clock is accomplished by the first D flip-flop in the 'S174 shift register (timing chain).

$\overline{RAS}$/$\overline{CAS}$

When $\overline{RAS}$ is enabled by a cycle request, it is qualified with either a refresh request (all $\overline{RAS}$'s turn on) or the decoded upper two bits of the address bus. A careful reader may question whether address is valid prior to $\overline{RAS}$ being enabled. This question can be answered by noting that the 8212 passes the address through before the falling edge of ALE latches it. T_{AL}† (115 ns for 320 ns 8085A processor cycle), which is the time from address to the falling edge of ALE, gives ample time for addresses to be valid at the 3242 outputs before $\overline{RAS}$ is valid. $\overline{RAS}$ is extended past the clearing of the cycle request flip-flop by ORing this enabling signal with a tap from the D flip-flop shift register.

$\overline{CAS}$ (Column Address Strobe) is produced between 123 and 164 ns after $\overline{RAS}$, depending upon when the first D flip-flop in the shift register synchronizes with the cycle request signal (C). Since this is greater than the specified maximum delay from $\overline{RAS}$ to $\overline{CAS}$, this memory system is $\overline{CAS}$ access limited and $\overline{RAS}$ access no longer has any meaning. The $\overline{CAS}$ tap can't move up one D flip-flop to provide more time for memory access as this would not provide sufficient data set up time with respect to $\overline{CAS}$ during a write.

†Note that T_{AL} now only applies to the high order address byte. TALL, for the lower address byte equals 90 ns. This was done to allow for additional T_{RAE} time for data float.

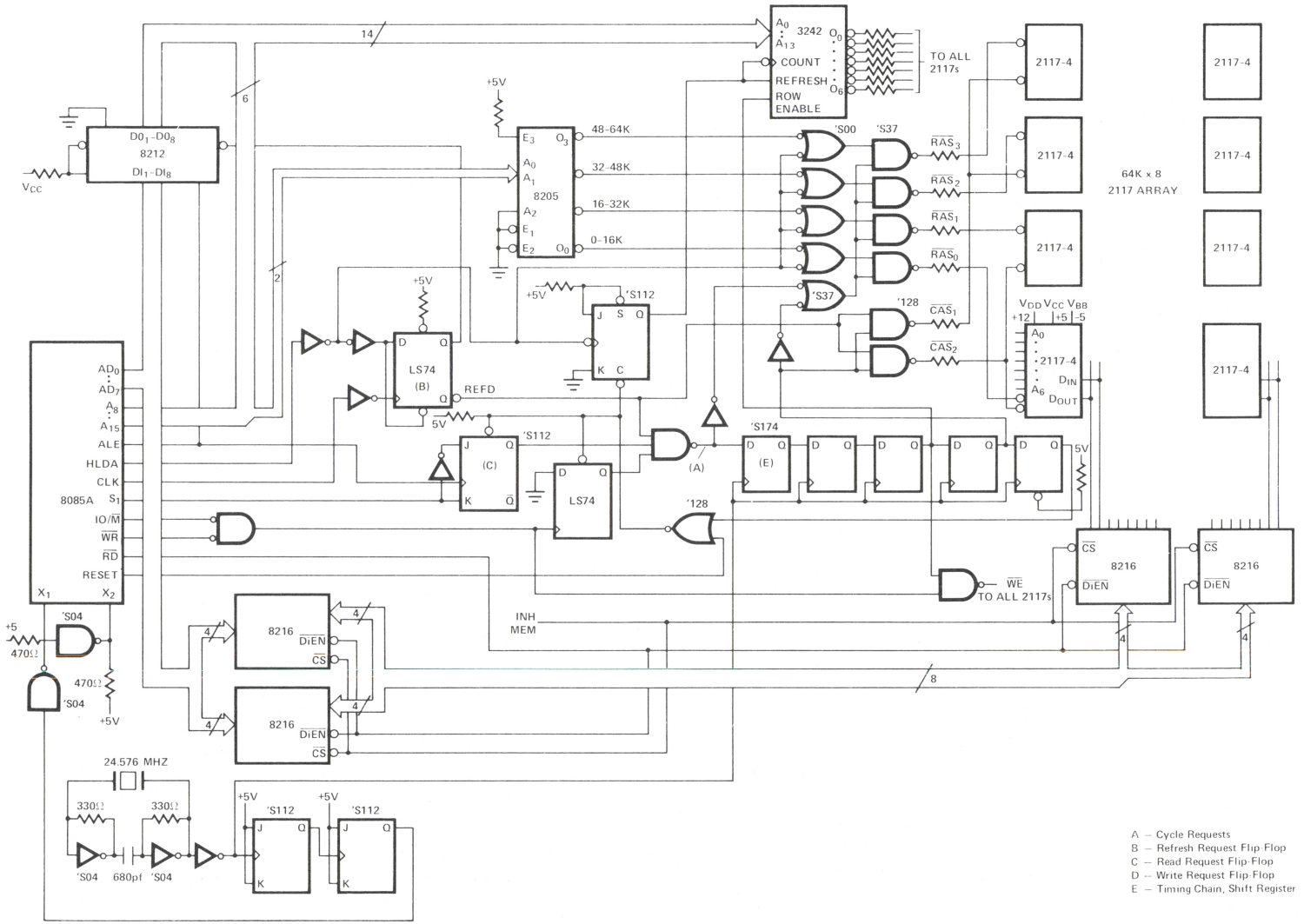


Figure 10. 8085A-2117 Dynamic RAM Interface

Data

The data path to the 2117s is through two sets of buffers to account for memory being off board. To determine bus timing it is helpful to know that Write data is not guaranteed to be valid from the 8085A until 40 ns after the leading edge of the write control signal. On account of this and the delay times for the buffers it is necessary to delay the cycle request on a write until the $\overline{WR}$ signal goes low. The solution shown still does not require wait states. An inhibit memory signal is also involved. This is useful when using memory address space overlap such as the case with bootstrap ROM (which would be necessary in this system if a full 64K of dynamic RAM is used).

Refresh

Dynamic RAMs are generally refreshed in two different modes; burst (i.e., all at once every 2 ms) and distributed (one row every (2 ms/number of rows) period of time). The schematic shown provides for a distributed refresh where refresh requests are applied to the Hold request input of the 8085A (not shown). This signal needs to occur at least once every 15 μsec ((2ms/128 rows to be refreshed) - HOLD to HLDA delay) and can be generated through a baud rate timing chain, Intel 3222, one shots or other similar devices. Another approach to refresh could qualify the refresh cycles with program fetch cycles (use status lines). If program memory is in static RAM or ROM and the dynamic RAM bus can be isolated, refresh cycles can be performed with no overhead. Instead of using the HOLD feature of the 8085A, refresh can be hidden in the program fetch and decode. Further considerations for refresh include proper handling of resets and excessive hold times from other peripherals to be certain the memory is being refreshed adequately.

Some applications don't require high CPU efficiency and require a very inexpensive method to refresh their dynamic RAM. Since writing, reading or performing special refresh cycles all refresh a particular row, why not do "dummy" reads to refresh? To use this technique memory must be mapped on a one to one correspondence with the address space. This will allow the programmer to read one byte in each physical row in the 2117s, thereby refreshing that row. A simple software routine can be devised to refresh 16K bytes of RAM. If more dynamic RAM than this is desired it can be accomplished by specially enabling all the desired RAS signals via an 8085A output port. First let's analyze how many CPU cycles are available in the 2ms period:

2ms/(320 ns/cycle) = 6,250 cycles
for 8085A@ 3.125 MHz

2ms/(200 ns/cycle) = 10,000 cycles
for 8085A-2@ 5.0 MHz

If there is a convenient component that can count 8085A cycles (8085A CLKOUT) and interrupt the 8085A, you're home free. An example of such a device is the 8155 in the MCS-85 family. On the 8155 one can use the $\overline{TO}$ ($\overline{\text{timer out}}$) pin to interrupt the CPU everytime a refresh needs to be performed and an interrupt service routine could dummy read 128 consecutive locations and return to CPU operation. (128 reads are necessary to completely refresh the full 16K bytes of 2117 memory.) The highest priority interrupt should be used for this to insure that refresh occurs. Figure 11 is an example program to perform this burst dummy read refresh. This routine basically uses 64 pops of the stack, each reading two consecutive locations in the memory. Note that this routine destroys the contents of registers B, C and D in the 8085A. The user may want to save these registers in the routine before performing the software refresh. If memory space is more valuable than CPU efficiency, the POPs can be performed in a loop instead of a string, saving additional memory.

This routine requires 690 cycles which is about 11% of the available 8085A CPU cycles, or 7% of the available 8085A-2 cycles. If this is acceptable and there is a counter available, you can't find a cheaper way to do refresh. Note that as processor speeds become faster, this overhead becomes proportionately less and more attractive as an alternative. Again, as with any refresh routine, reset and excessive holds must be dealt with to guarantee proper refresh.

DMA (Direct Memory Access)

DMA is becoming more common in the microcomputer system for many applications. Some examples include the 8271 floppy disk controller and refreshing a CRT via an 8275 CRT Controller. It is always helpful to reduce the overhead of the DMA (as DMA can tie up the system bus) whenever possible. In many applications, where program memory is resident in ROM or PROM, DMA cycles can be performed in coincidence with op code fetch. This will make them invisible to the CPU as described for Refresh in the Refresh section of the 2117 dynamic RAM example.

In the dynamic Ram system, Refresh requests can be made on the DMA controller via the DRQ lines, with the 8237 in a rotating priority mode to insure refreshing is done. Another technique would be to devise an arbiter for DMA and refresh requests at the processor hold input. With this technique the designer must not allow DMA to monopolize the bus when refresh is needed.

```
During initialization:
   MVI          A, D5H   SET TIMER COUNT TO 5550* FOR REFRESH COUNT
   OUT    TIMER MSBYTE
   MVI          A, A4H   INTERRUPT CPU AT TO (TIMER OUT)
   OUT     TIMER LSBYTE
   MVI          A, C0H   START COUNTER, PLACE C0 IN 8155 STATUS REG.
   OUT  TIMER COMMAND
   Program

AT RST 7.5 RETURN ADDRESS      CALL RFRS     (REFRESH SERVICE)
TOTAL      #CYCLES
CYCLES
            10          RFRS:  LXI HL, 0     SAVE STACK POINTER IN HL
            10                 DAD SP
 30         10                 LXI SP, 0080  32K - 48K REFRESH

            10                 POP BC
            10                 POP BC        REFRESH, DUMMY READ
                               .
                               .
                               .             64 TIMES
                               .
640
            6                  SPHL          RESTORE STACK POINTER
            4                  EI            ENABLE INTERRUPTS
 20         10                 RET           RETURN

690         TOTAL CYCLES       (round up to 700)
```

*6,250 available cycles - 700 to do refresh. Counter should count 5550 = 15A4H for 8085A; for 8085A-2 must count 10,000-700 = 9300 = 2454H. To set counter to automatic reload, most significant bits in timer of 8155 must be set to 1. Therefore, for 8085A use D5A4H and for 8085A-2 use E454H.

Figure 11. Software Refresh

The standard technique for interfacing the 8085A processor to the 8237 DMA controller is shown in the MCS-85 User's Manual and is reproduced in Figure 12. This configuration is set up to interface with standard memories or peripherals, i.e., ones that don't share their data bus with addresses, not the MCS-85 family components (8155, 8355, 8755A, etc.). DMA is unlikely with these MCS-85 components as they are intended for minimum system applications. If the system has both MCS-85 and standard addressed components, and DMA is used for the standard addressed components, ALE must be or'ed with ADSTB from the 8257. This is necessary to deselect the MCS-85 components from the bus. Due to the latching feature of the MCS-85 components, bus contention may result if this is not done and DMA tries to use the bus.

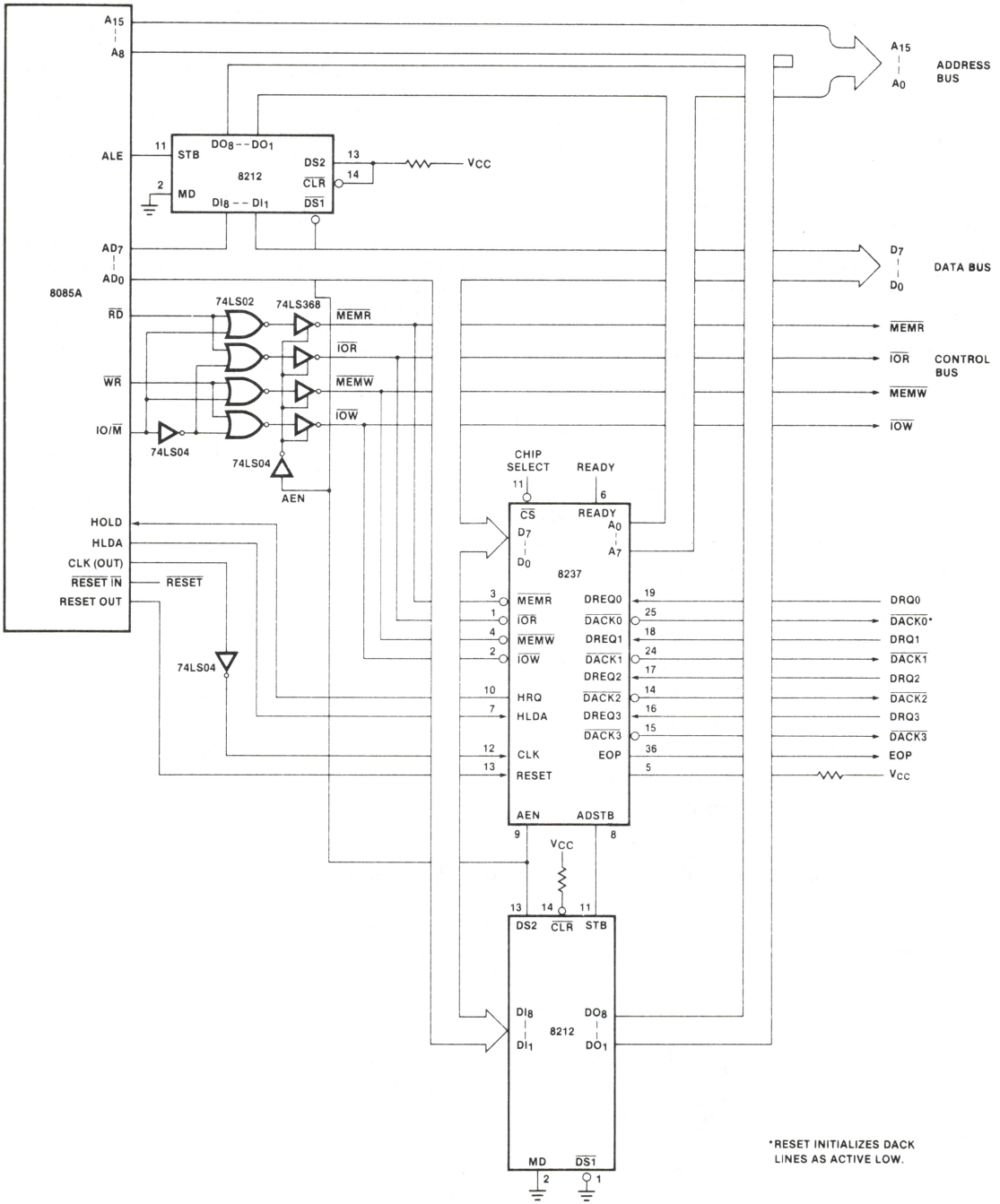


Figure 12. Detailed System Interface Schematic

SYSTEM TIMINGS

8085A CLK-IN vs. CLK-OUT vs. Control Timings

This section shows timing characteristics that relate the input clock to the control signals and the output clock. These timings can be treated as constants, that is, within the normal operative range of the processor, they are cycle or 8085A, A-2 speed independent.

Be careful about manipulating the timings given in this section with the specifications in the data sheet. The specifications on the 8085A, A-2 are *not* mutually exclusive; that is, you can't add minimums to minimums and obtain a valid minimum for some other timing parameter. Where the timing parameter is specified directly, this takes precedence over any other method you come up with to find that specification (through adding and subtracting others). This was not done to confuse the user, but to provide him with the most optimal timings for his system!

To understand the timing parameters in this section it would be helpful to understand how the internal signals are generated in the 8085A. Referring to Figure 13, it is seen that the rising edge of the X1 input causes flip-flop A to toggle. From this flip-flop two internal signals are generated that drive all functions in the 8085A, A-2 and produce the output control signals and clock. Referring to Figure 15, it is seen that clock output is derived from the internal $\phi 1$ signal in the schematic of Figure 14. This output signal is a MOS output unlike the bipolar outputs of the 8224 in the 8080A system. This restricts the user to the loading limitations of a MOS driver (for further details see bus loading section). The rest of the output control signals with their respective internal controlling edges are also shown in Figure 14.

Since the path between the X1 input and the clock output can have a considerable amount of variance, the relationships of these two clocks vary significantly. Figures 15 and 16 are a set of timing diagrams illustrating the relationship of the clock input to the clock output to the various control signals. For designs that require these relationships to synchronize different systems, components, etc; the designer must allow for these variances in the relationships.

Parameter	Description	Min	Max	Units
$t\phi AL$	Time from C.F. to next Address valid (A_0 - A_7)		130	ns
$t\phi ALU$	Time from C.F. to next Address valid (A_8 - A_{15} only)		70	ns
$t\phi AT$	Time from C.F. to present Address remaining valid (A_8 - A_{15} only)	−20		ns
$t\phi CL$	Time from C.F. to control low (L.E.)	−10	60	ns
$t\phi CT$	Time from C.R. to control low (T.E.)	−10	60	ns
$t\phi DL$	Time from C.F. to Data Out becoming valid		65	ns
$t\phi DT$	Time from C.F. to Data Out remaining valid	−20		ns
$t\phi DS$	Data-in set up time to C.R.	100		ns
$t\phi DH$	Data-in hold time to C.R.	0		ns
$t\phi LL$	Time from C.F. to ALE high (L.E.)	−60	0	ns
$t\phi LT$	Time from C.R. to ALE high (T.E.)	0	70	ns
$tXKF$	Time from X_1 input to C.F.	30	150	ns
$tXKR$	Time from X_1 input to C.R.	30	120	ns

C.F. = Clock Falling, C.R. = Clock Rising, L.E. = Leading Edge, T.E. = Trailing Edge

NOTE: These numbers are guaranteed by design and are not tested by Intel.

8085A, 8085A-2 Clock Parameters

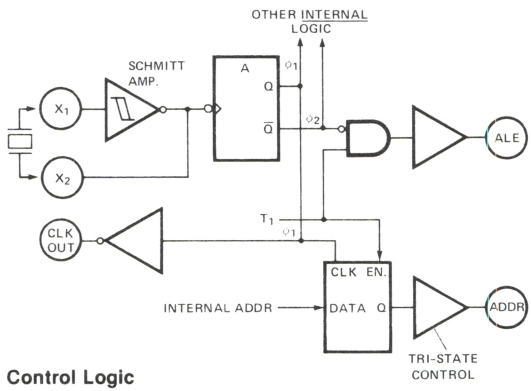


Figure 13. Clock and Sample Control Logic

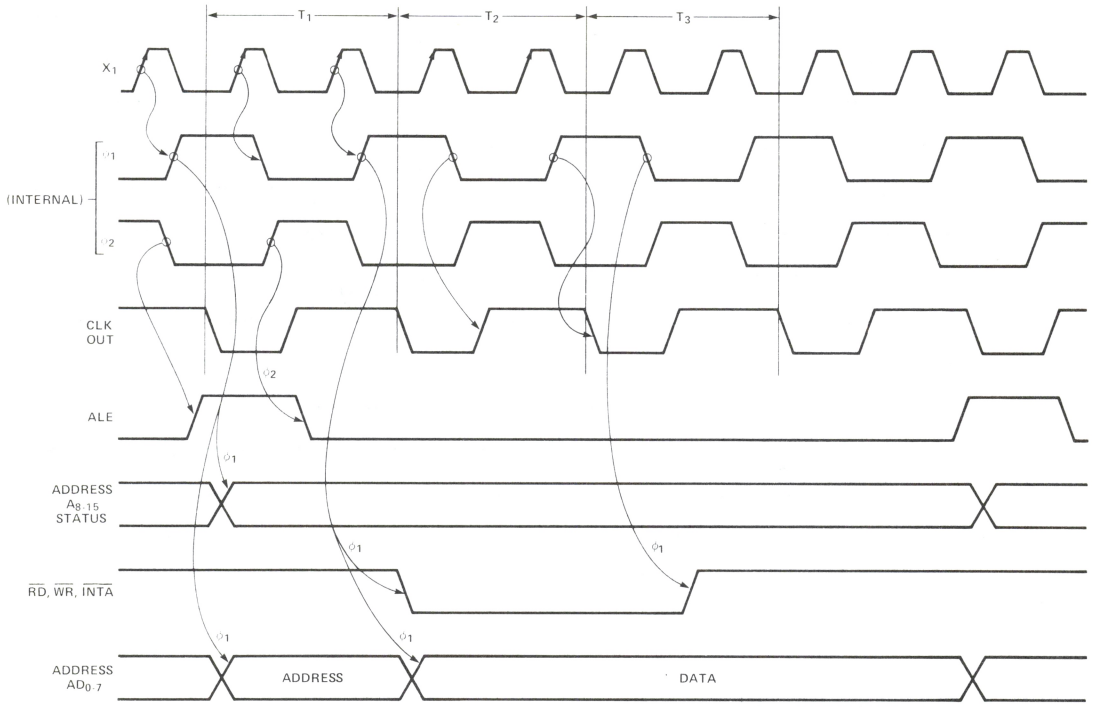


Figure 14. Clock In (X1) to Output Relationship

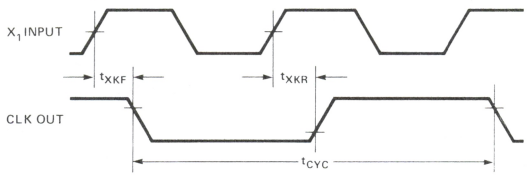


Figure 15. 8085A-2 Clock In/Clock Out Timing

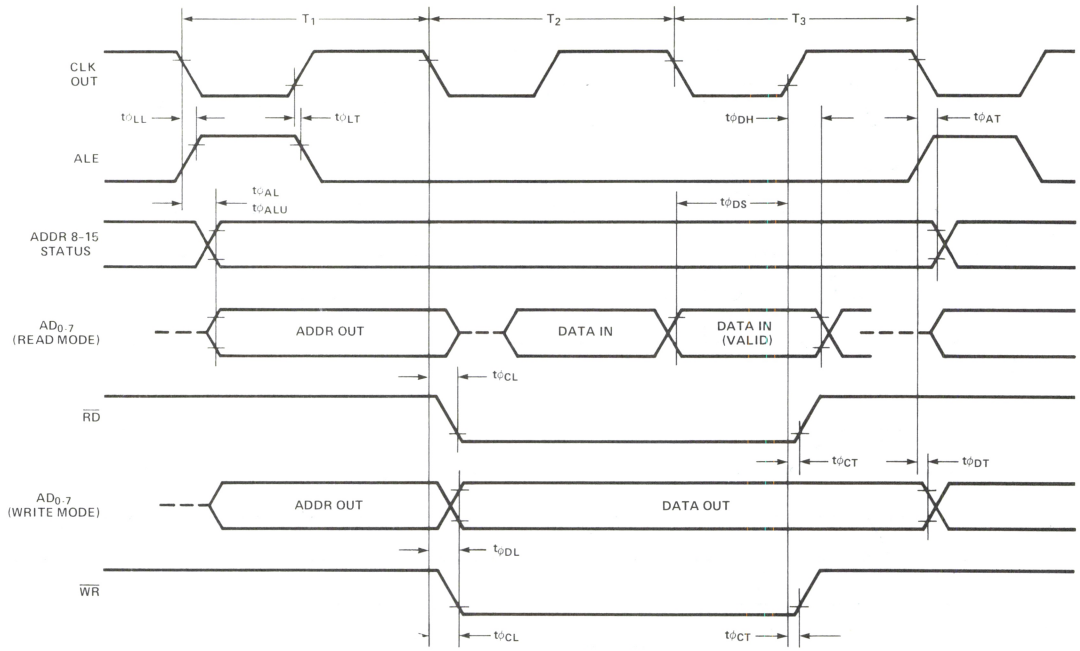


Figure 16. 8085A-2 Clock Related Timing

3.125 vs. 5 MHz Considerations

The 8085A (with maximum internal clock frequency of 3.125 MHz) and 8085A-2 (5 MHz) have some differences in their bus operation. There are two sets of peripherals that can be used with both the 8085A and A-2. There are the dedicated peripherals in the MCS-85 family that directly interface with the 8085A, A-2 bus and the standard MCS-80 peripherals that Intel also provides. The standard peripherals that are denoted 825X-5 (also the 8251A and 827X peripherals) are peripherals that can be used with an 8085A or 8085A-2. In the 8085A-2 system a wait state is required for proper I/O operation, but even with this wait state system speed is still 30% higher than the 8085A without wait states. An example wait state generator for this purpose is shown at the end of the peripheral compatibility section in this Application Note (Figure 19).

The main timing differences to consider when using an 8085A vs. an A-2 are listed in Table 1.

Cycle dependent timings are listed in Table 2. These are very useful when the user is not operating at the full bus speed. Remember that each 8085A, A-2 device divides its clock input frequency by 2. Therefore, a 10 MHz crystal will produce a 200ns output cycle (denoted as T in the cycle dependent timings). A timing diagram showing the relationships of the timing parameters given in Table 2 can be found on the data sheets.

—Clock (crystal) requirements. The 8085A, A-2 requires the following crystal specifications to run at top bus speed:	
8085A	6.25 MHz frequency, parallel resonant, fundamental, 10 mwatt drive level, RS < 75 ohms, CL = 20-35 pf, and CS < 7 pf.
8085A-2	10 MHz frequency, all other specifications the same as 8085A.
—Memory and Peripheral Compatibility - Discussed in detail in upcoming sections.	
—Cycle dependent timings (Table 2)	

Table 1. 8085A vs. 8085A-2.

Parameter	3.125 MHz (8085A) (ns) Min	Max	Cycle Dependencies	5 MHz (8085A-2) (ns) Min	Max	Cycle Dependencies
tcyc	320	2000		200	2000	
t1	80		1/2T—80	40		1/2T−70
t2	120		1/2T—40	70		1/2T−50
tr		30			30	
tf		30			30	
tAL	115		1/2T−45	50		1/2T−50
tLA	100		1/2T−60	50		1/2T−50
tLL	140		1/2T−20	80		1/2T−20
tLCK	100		1/2T−60	50		1/2T−50
tLC	130		1/2T−30	60		1/2T−40
tAFR		0			0	
tAD		575	(5/2+N)T−225		350	(5/2+N)T−150
tRD		300	(3/2+N)T−180		150	(3/2+N)T−150
tRDH	0			0		
tRAE	150		1/2T−10	90		1/2T−10
tCA	120		1/2T−40	60		1/2T−40
tDW	420		(3/2+N)T−60	230		(3/2+N)T−70
tWD	100		1/2T−60	60		1/2T−40
tCC	400		(3/2+N)T−80	230		(3/2+N)T−70
tCL	50		1/2T−110	25		1/2T−75
tARY		220	3/2T−260		100	3/2T−200
tRYS	110			100		
tRYH	0			0		
tHACK	110		1/2T−50	40		
tHABE		210	1/2T+50		150	1/2T+50
tRV	400		3/2T−80	220		3/2T−80
tAC	270		T−50	115		T−85
tHDS	170			120		
tHDH	0			0		
tINS	360		1/2T+200	150		1/2T+50
tINH	0			0		
tLDR		460	2T−180		270	4/2T−130

Where T = tcyc and N = the number of wait states that are incorporated.
All mathematical operations in Table 2 are performed from left to right, except where qualified with parenthesis.

Table 2. 8085A and 8085A-2 Cycle Dependencies

Memory Device Compatibility

Determining What Memory to Select For Your Application

When developing a system which will use sufficient memory to require buffering (see the capacitive loading section to determine when it is needed), it is important to understand how to select the slowest, lowest cost memory and still be compatible with the bus timings with minimum wait states. A generalized procedure has been developed in the following section for determining the memory access needed for different applications and the number of wait states required (if any). In general the amount of time available for accessing the memory can be obtained from the following formula:

Available memory access = 8085A access time (from control signal of interest) - Buffering/Decoding delay (to and from memory)

The three main "control" signals of interest which determine memory access are that of t_{RD} (read to valid data in), t_{AD} (valid address to valid data in) and t_{LDR} (address latch enable to valid data in). When dealing with different types of memories, one or more of these signals becomes important.

Even though memory access compatibility is probably one of the most important parameters to consider, as this is directly reflected in the price of the memory, it is not the only parameter that is important. Some of the other major timing considerations are as follows:

WRITE ENABLE - Is the write enable signal sufficiently long to guarantee a write?
Is data set up properly with respect to this write to be compatible with the memory's requirements?
Is data held long enough?

DATA FLOAT - Does your system have sufficient margin to prevent bus contention?
(i.e., Does the memory let go of the data bus in time for the processor to use it? Remember that the 8085A shares its Data Bus with the lower 8 addresses.)

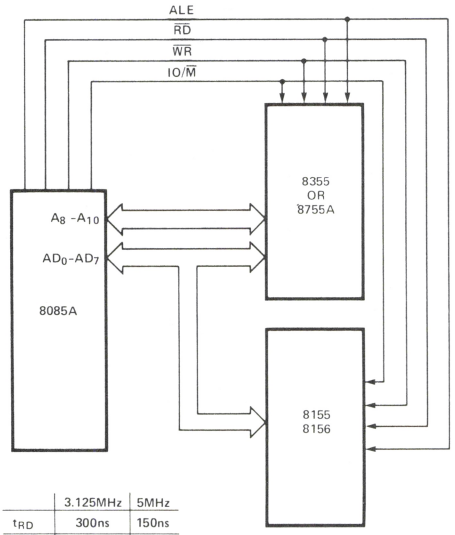
We will first go through the minimum system which can be represented by the dedicated set of components Intel has developed for the 8085A (Fig. 17). The two timing specs were taken from the data catalog for t_{RD} and t_{AD} (t_{LDR} is irrelevant here). Looking at the 8155/6 and 8355/8755A, a comparison can be made for the access times:

	8085A (3.125 MHz)	8155/6	8355/8755A
t_{RD}	300 (max)	170 (max)	170 (max)
t_{AD}	575 (max)	400 (max)	400/450 (max)

This shows that there is plenty of bus margin for the 3.125 MHz minimum application of the 8085A. Access time for the processor can be interpreted as the time from when the control signal is presented on the bus to the time when the processor will expect the data to be valid so it can sample it. Conversely, memory access times show the amount of time that will elapse between when it is told to present its information to when it actually does it. As long as the memory access spec is less than the processor access spec (minus appropriate buffering delays) the memory is access time compatible.

In more complicated systems where one level of data, address and control buffering is required (such as the case when there are many signal paths and device loading on one card), the delays of the latches and bidirectional drivers must be taken into consideration.

First consider a ROM, EPROM or static RAM configuration as shown in Figure 18. Using the generalized available memory access formula, t_{AD}, t_{RD} and t_{LDR} for the memory can be determined using the data sheet timing delays for the buffers.



	3.125MHz	5MHz
t_{RD}	300ns	150ns
t_{AD}	575	350

Figure 17. Minimum System

	3.125MHz	5MHz
T_{RD}	250	100
T_{AD}	500	275
T_{LDR}	390	200

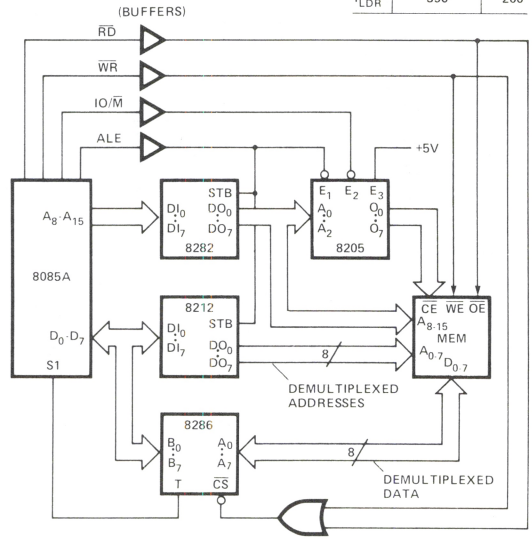


Figure 18. Medium Buffered System

t_{AD} MEMORY = t_{AD}8085A − (8282 + 8205 delay) − (8286 delay) + transitional gain due to buffering*

= t_{AD}85 − (T_{IVOV} + t--) − (T_{IVOV}) + t_{CAPB}*

= (5/2+N)T − 225 − 55 − 35 + 15

= (5/2+N)T − 300 (for 8085A)

(5/2+N)T − 225 (for 8085A-2)

where N = number of wait states and T = cycle time,

For minimum 8085A timing 500ns = t_{AD} memory

8085A-2 timing 275ns = t_{AD} memory

The 8085A timing parameter t_{AL} was not taken into consideration as the 8282 transfers information directly through without concern of the address latch enable. t_{RD} can be obtained in a similar manner.

The read signal $\overline{RD}$ goes through a buffer before it reaches the memory. This must be taken into consideration when calculating effective t_{RD} for the memory.

t_{RD} MEMORY = t_{RD} 8085A − (buffer delay) − (8286 delay) + transitional gain due to buffering

= t_{RD} 85 − (delay) − (T_{IVOV}) + t_{CAPB}

= (3/2+N)T − 180 − 30 − 35 + 15

= (3/2+N)T − 230 (for 8085A)

(3/2 + N)T − 200 ns (for 8085A-2)

*t_{CAPB} is additional time thrown back in for improvement in signal transitions. This is because buffering the signals reduces the capacitive loading considerably. The data sheet gives timings for maximum capacitive loading. Characterization has shown change in delay versus capacitive loading as .12 ns/pf min (under 20 pF loading) and .24 ns/pF max (under 150 pF loading). To take into consideration the effects of this loading two parameters are defined:

t_{CAPA} - delay for a signal to leave the old logic level

t_{CAPB} - delay for a signal to complete the transition from the old to new logic level

where t_{CAPA} = 1/2 t_{CAPB}

	MIN	MAX
t_{CAPA}	7 ns	15 ns
t_{CAPB}	15 ns	30 ns

In the memory compatibility calculations tCAPB min is added on as spec sheet values assume 150 pF loading and this system is not worst case, i.e., it has buffering that reduces this loading to approximately 20 pf. Since the CAP = 130 pF and change in delay versus capacitance is 1/2 ns/pF min, t_{CAPB}MIN = (.1 ns/pF) 130 pF = approx. 15 ns.

For minimum 8085A timing 250ns = t_{RD} memory

8085A-2 timing 100ns = t_{RD} memory

Therefore for t_{LDR}:

t_{LDR} MEMORY = t_{LDR} 8085 − (buffer delay) − (8205) − (8286) + t_{CAPB}

= t_{LDR} − (delay) − (t--) − (T_{IVOV}) + t_{CAPB}

= 2T −180 −30 −20 −35 +15

= 2T −250 for 8085A

= 2T −200 for 8085A-2

For minimum 8085 timing = 390ns

8085A-2 timing = 200ns

To obtain memory access parameters for a multicard system (which would have buffering at both ends of the system bus), it is a simple matter of subtracting off the additional buffering delays.

With these timings a memory compatibility table can be developed from the data sheets (Table 3). With most of these memories it is relatively straightforward to determine the controlling signal used to select and enable the device. To illustrate this, listed below are the controlling signals of interest for the different memories as they are used in a typical configuration:

		Relevant Control Signal
RAM		
2114		
	Address access	- t_{AD} MEM
	Chip select access	- t_{LDR} MEM**
2142		
	Address access	- t_{AD} MEM
	Chip select access	- t_{LDR} MEM**
	Output enable	- t_{RD} MEM
ROM		

**Chip selects for these static RAMs need not be qualified with ALE. If 2114 or 2142 chip selects are generated directly from the address lines, the relevant timing is t_{AD} MEM.

	3.125 MHz	5 MHz
MINIMUM SYSTEM:		
STATIC RAM	8155/8156, (256x8) 8185 (1Kx8)	8155-2/8156-2 8185-2
ROM/EPROM	8355 (2Kx8) 8755A (2Kx8)	8355-2 8755A-2
BUFFERED SYSTEM:		
STATIC RAM	2114 (1Kx4) 2142 (1Kx4)	2114-2 2142-2
ROM/EPROM	2732 (4Kx8) 2716-2 (2Kx8)	 2716-2**

*Contact Intel for high performance EPROM/ROM Family.
**With 1 wait state.

Table 3. 8085A, A-2 Memory Compatibility.

In general, t_{AD} MEM and t_{LDR} MEM are the parameters needed for chip enabling, selection and address access times, and probably are the most important considerations when determining which memory device to use. When there is an output enable, tRD MEM is also used. All relevant access times must be met by the resulting system configuration to be compatible.

This note will not attempt to generalize a procedure that deals with the interface to dynamic RAM, but the 2117 example shown earlier is described below. In the dynamic RAM system, many variables come into play upon which the memory access is dependent. Among these are refresh controllers, decoding, whether or not the system is designed for minimum hardware or maximum performance, and consideration for nonmultiplexed vs. multiplexed address dynamic RAMs.

For the Intel 2107C, which has nonmultiplexed addresses, tAD is the important parameter as it generates the chip selects and chip enables. However, with a multiplexed address part, things are different and both a $\overline{RAS}$ and $\overline{CAS}$ access time must be considered. Note that since $\overline{RAS}$ is applied before $\overline{CAS}$, $\overline{RAS}$ access time is effective only while the $\overline{CAS}$ signal stays within the specified $\overline{RAS}$ to $\overline{CAS}$ delay time. If it is not possible to do this, $\overline{CAS}$ access becomes the limiting factor for memory selection. Don't be mislead by the $\overline{RAS}$ to $\overline{CAS}$ maximum delay (tRCD: $\overline{RAS}$ to $\overline{CAS}$ delay time) spec'd on dynamic RAM data sheets! This maximum only applies to guarantee $\overline{RAS}$ access.

For a specific example the following shows how the speed versions were selected for previous 2117 dynamic RAM interface.

$\overline{RAS}$ path (from ALE)	approximate delay
5 gates	7 ns ea
1 Flip Flop	15 ns
(return path) 2 8216s	25 ns ea

$\overline{CAS}$ path (from ALE)	approximate delay
3 gates	7 ns ea
1 Flip Flop	15 ns
4 D Flip Flops	41 ns ea

t_{ACCESS} AVAILABLE FOR $\overline{RAS}$ =

$$t_{LDR} - 5(7) - 15 - 2(25) = 360 \text{ ns}$$

t_{ACCESS} AVAILABLE FOR $\overline{CAS}$ =

$$t_{LDR} - 3(7) - 15 - 4(41) - 2(25) = 210 \text{ ns}$$

Since $\overline{RAS}$ available time – $\overline{CAS}$ available time is greater than the spec value for $\overline{RAS}$ to $\overline{CAS}$ delay on all 2117 specs, $\overline{CAS}$ access becomes the limiting factor. A $\overline{CAS}$ access of 165ns of the 2117-4 is well within the time available.

To verify the other 2117 specs such that there is certainty that this sytem will play, a comparison can be made of the timing specs in the 2117 data sheet to the timings that result in the circuit configuration in Figure 12. When looking at the following timing comparisons, remember that the read cycle is initiated by the falling edge of ALE (Address Latch Enable) and the write from the falling edge of $\overline{WR}$ (Write). For descriptions of the parameters in Table 4, please refer to a 2117-4 data sheet. Delay assumptions used are shown in Table 5.

READ CYCLE	TAKEN FROM 2117-4 DATA SHEET MIN	TAKEN FROM 2117-4 DATA SHEET MAX	DYNAMIC RAM CONFIGURATION MIN	DYNAMIC RAM CONFIGURATION MAX
tRAC		250 ns	Doesn't apply	
tCAC		165 ns	210 ns	
tREF		2 ms	Not Shown	
tRP	150 ns		279 ns	
tCPN	25 ns		472 ns	
tCRP	–20 ns		193 ns	
tRCD	35 ns	65 ns	Outside spec, CAS access limited	
tRSH	165 ns		177 ns	
tCSH	250 ns		300 ns	
tASR	0 ns		55 ns	
tRAH	35 ns		82 ns	
tASC	–10 ns		–4 ns	
tCAH	75 ns		205 ns	
tAR	160 ns		410 ns	
toff	70 ns		See Below*	
tRC	410 ns		720 ns	
tRAS	250 ns		307 ns	
tCAS	165 ns		198 ns	

*There are two parameters that the processor "sees". One is memory access, which has already been covered. The other is when the memory will let go of the bus. To show compatibility here, the following analysis is done:

2117	t_{OFF}	70 ns max
8085A	t_{RAE}	150 ns min

Therefore compatible as $\overline{WR}$ is used to deselect the 8216's.

Table 4. Bus Compatibility Analysis (see Figure 11)

WRITE CYCLE	TAKEN FROM 2117-4 DATA SHEET MIN	MAX	DYNAMIC RAM CONFIGURATION MIN	MAX
tRC	410 ns		720 ns	
tRAS	250 ns		307 ns	
tCAS	165 ns		198 ns	
tWCS	−20 ns		34 ns	
tWCH	75 ns		164 ns	
tWCR	160 ns		287 ns	
tWP	75 ns		205 ns	
tRWL	100 ns		205 ns	
tCWL	100 ns		205 ns	
tDS	0 ns		23 ns **	
tDH	75 ns		Data held until next cycle	
tDHR	160 ns		Data held until next cycle	

**Data is not valid from the 8085A until 40 ns after $\overline{WR}$ falls.

Table 4. Bus Compatibility Analysis (see Figure 11) (Cont'd)

The numbers in Table 4 were obtained by using the following delay assumptions (Table 5) and very conservative techniques of obtaining minimum 8085A timings. Where no direct specification applied, minimum specs were added assuming 0 ns for any rise or fall times. This is more conservative than necessary. Another approach can be made from the clock related timings discussed in an earlier section.

	DELAY MIN	MAX	
Gates	0 ns	7 ns	
Flip Flops	0 ns	15 ns	
8216s	0 ns	30 ns	
D flip flop (Timing Chain)	41 ns	41 ns	
3242	0 ns	25 ns	(Min 0ns for
8212	0 ns	30 ns	synchronization D FF)

Table 5. Delay Assumptions

An exhaustive approach as Table 4 will more than pay itself back in terms of debugging the circuit. However, while this analysis may be helpful in understanding an existing circuit, it won't help as much in creating a new one. A general procedure for designing with memories is itemized below:

1. Determine how much processor time is available for memory access. Access from addresses is the most important parameter.
2. Determine how much buffering will be used (both to and from the memory) and how much delay there will be due to decode or qualifications in the circuit (in the memory design in Fig. 11, $\overline{WR}$ qualifies a write). Subtract these resulting delays from step 1 to get an effective access for the memory. If multiplexed address RAM is used go to 3, if not go to 4.
3. Determine how the $\overline{RAS}$ and $\overline{CAS}$ timings will be generated, be it one shots, delay lines, shift registers, etc. Adjust memory access available for the method chosen.
4. Select a memory that meets this criterion.
5. Design the system to meet all the specified parameters of the memory and verify.

Steps 1, 2 and 4 have been done for you in the Memory Compatibility Table for ROM, EPROM and Static RAM memories in a medium and minimum system. *Remember* - for dynamic RAM, Intel will soon be providing an 8202, a refresh, dynamic RAM controller that generates all $\overline{RAS}$, $\overline{CAS}$ control signals for a 64 kByte memory (made of 2117s).

Peripheral Compatibility - 3.125 and 5 MHz

Intel supports its processors with many LSI peripheral components that do a wide range of functions to simplify circuit design. The 8085A compatible peripherals have been denoted the "−5" notation to show compatibility. The "−5" notation also signifies that these devices are compatible with the 8085A-2 with one wait state interjected. This wait state is produced by taking the ready line low at the proper time as shown in Figure 19.

A list of these peripherals is shown in Table 6 with corresponding relevant specifications to illustrate 8085A-2 compatibility. The analysis for determining the resulting timings is similar to the analysis in the previous memory compatibility section.

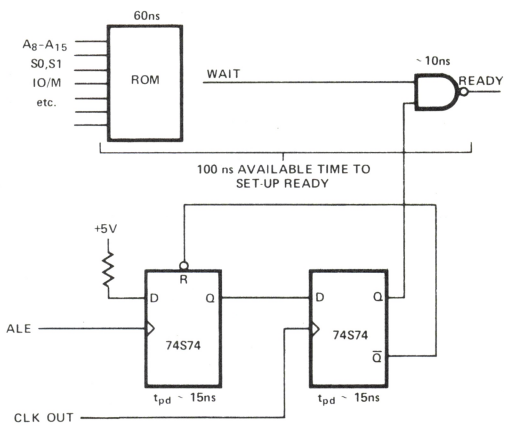


Figure 19. 8085A-2 Wait State Generator

Part No.	AC. Parameter	Min. (ns)	Max. (ns)	8085A-2 AC. Parameter	Margin vs. −2 Spec. (ns)
8251A	t_{RD}		200	t_{RD}	*150
	t_{RA} & t_{WA}	0		t_{CA}	60
	t_{DW}	150		t_{DW}	80
	t_{WD}	0		t_{WD}	60
	t_{RR} & t_{WW}	250		t_{CC}	*180
	t_{AR} & t_{AW}	0		t_{AC}	
8253-5	t_{RD}		200	t_{RD}	*150
	t_{RA}	5		t_{CA}	55
	t_{WA}	30		t_{CA}	60
	t_{DW}	250		t_{DW}	*180
	t_{WD}	30		t_{WD}	30
	t_{RR} & t_{WW}	300		t_{CC}	*130
	t_{RV}	1000		t_{RV}	**
	t_{AR} & t_{AW}	50		t_{AC}	65
8255A-5	t_{RD}		200	t_{RD}	*150
	t_{RA}	0		t_{CA}	60
	t_{WA}	20		t_{CA}	40
	t_{DW}	100		t_{DW}	130
	t_{WD}	30		t_{WD}	30
	t_{RR} & t_{WW}	300		t_{CC}	*130
	t_{RV}	850		t_{RV}	**
	t_{AR} & t_{AW}	0		t_{AC}	115
8257-5	t_{RD}		200	t_{RD}	*150
	t_{RA} & t_{WA}	0		t_{CA}	60
	t_{DW}	200		t_{DW}	30
	t_{WD}	0		t_{WD}	60
	t_{RR}	250		t_{CC}	*180
	t_{WW}	200		t_{CC}	30
	t_{AR}	0		t_{AC}	115
	t_{AW}	20		t_{AC}	95
8271 & 8273	t_{AD}		200	t_{AD}	*350
	t_{RD}		150	t_{RD}	*200
	t_{CA}	0		t_{CA}	60
	t_{DW}	150		t_{DW}	80
	t_{WD}	0		t_{WD}	80
	t_{RR} & t_{WW}	250		t_{CC}	*180
	t_{AC}	0		t_{AC}	115
8275	t_{RD}		200	t_{RD}	*150
	t_{RA} & t_{WA}	0		t_{CA}	60
	t_{DW}	150		t_{DW}	80
	t_{WD}	0		t_{WD}	60
	t_{RR} & t_{WW}	250		t_{CC}	*180
	t_{AP} & t_{AW}	0		t_{AC}	115
8279-5	t_{AD}		250	t_{AD}	300
	t_{RD}		150	t_{RD}	200
	t_{RA} & t_{WA}	0		t_{CA}	60
	t_{DW}	150		t_{DW}	80
	t_{WD}	0		t_{WD}	60
	t_{RR} & t_{WW}	250		t_{CC}	*180
	t_{RCY}	1000		t_{RV}	**
	t_{AP} & t_{AW}	0		t_{AC}	115

*With 1 "Wait State"
**Must allow for in Software

Table 6. Peripherals vs. 8085A-2

Taking note of asterisked margins shown on the comparison sheet: t_{AD}, t_{RD}, t_{RR} and t_{DW}, it is seen that they are all taken care of by introducing a wait state. The double asterisked margins deal with the t_{RV} spec on the 8255A-5, 8253-5 and 8279-5 peripherals. t_{RV} is the time from the rising edge of $\overline{WR}$ or $\overline{RD}$ to the next falling edge. To allow sufficient time for this spec it is necessary to delay the commands sent to these three peripherals. Enough dead time must occur to make up for the entire negative portion of the margin (for example: 790ns in the 8253-5 medium system). Since in the 8085A-2 every machine cycle is at least 200ns long, 4 machine cycles are sufficient time to allow peripheral control signal recovery (t_{RV}).

One may notice that all of the 8085A instructions take at least 4 T-states (providing a minimum of 800ns) giving ample time to meet this requirement, just by programming one instruction in between every command sent to the peripheral. I/O mapped I/O, which results in using the Input, Output instructions has this delay time built in when moving the data to be transferred into the accumulator. With memory mapped I/O, any instruction that accesses memory for data will provide the time necessary to not violate t_{RV} as a second fetch is performed.

Bus - Loading Considerations - Decoupling

For the cost conscious designer it is always helpful to know when buffering is needed and when it is not. How much can I load the 8085A output pins down? To answer this it is helpful to first list the DC requirements of the common types of logic loading and compare this to the capabilities of the 8085A.

	Maximum High-Level Input Current	Maximum Low-Level Input Current
TTL (single load)	40μA	1.6mA
Schottky or HTTL	40μA	2.0mA
MOS	10μA	10μA
LSTTL (single load)	20μA	400μA

The 8085A is capable of an IOL of 2mA (low) and IOH of $-$ 400μA. With this spec it is easy to come up with the possible combinations of D.C. loading that the designer can use without buffering:

LOADS	8085A, A-2 limiting factor (level)
1 TTL + 1 LSTTL	LOW
1 TTL + 36 MOS*	HIGH
1 SCHOTTKY or 1 HTTL	LOW
40 MOS (various combinations possible)*	HIGH
5 LS TTL	LOW

* Exceeds capacitive loading limit, to be discussed

If a user exceeds these DC loading limitations he must buffer that particular signal. Another factor that the designer **must** consider is the capacitive load that is seen by the 8085A outputs, which may very well be excessive even if DC loading is not. One may note that even though the 8085A can handle a DC load of 40 MOS devices or 36 MOS + 1 TTL, their collective input capacitances exceed the 150 pF max spec.

The timing specs of the 8085A are guaranteed as long as the 150 pF maximum loading is not exceeded, which includes the wires, components and parasitics. If the user exceeds this value and wants to guarantee his system timing he must either derate the system timings or use buffering.

What if you choose to ignore this limit and say you can live with the performance degradation? First the timing performance is not all that would degrade, a user must be willing to give up some reliability of his components (All MOS devices have this restraint). This is caused by the excessive switching currents that are needed for this extra loading capacitance. If reliability is not an important consideration, the user can load up to 300 pF on the 8085A bus, but the following correction factors must be used to adjust the timings:

for 150 pF $<$ 300 pF add .13 ns/pF

conversely if less than 150 pF:

for 25 $<$ CL $<$ 150 pF you can subtract .1/ns/pF.

What happens after 300 pF? If the user exceeds this, the noise levels become excessive and problems will result. How much is to much noise? 350 mvolts zero to peak. Prudent designers will always buffer when noise approaches this level, especially in the case of going from one board to another.

The above takes into consideration the actual specification considerations of when to buffer, but there are also transmission line and noise effects that must be considered. When working with dynamic RAMs small (20-30 ohm) resistors are commonly put in series in the address lines to help match impedance levels and reduce reflections. Note that this resistor should be chosen such that it does not severely degrade the voltage levels of the signal. Long parallel board traces with signals that could adversely affect each other should also be avoided to prevent cross talk problems.

By-passing is very important to prevent intermittent problems which often plague the board designer. Large bulk capacitors should be used at strategic locations on the board to prevent power supply droop. This becomes a major factor when there are many devices that can turn on at once and produce a considerable drain from the power supply (such as burst refresh in dynamic RAM).

To help smooth out the current spikes that naturally occur when devices turn on and off, it is recommended to liberally use small capacitors such as the monolithic and other ceramic capacitors which have low inherent inductance. Attached in the 2117 data sheet is a suggested layout of capacitors to effectively bypass the supply lines to ensure proper system operation. Cutting corners here will often times turn around and bite you.

Proper layout is an important consideration. Power supply lines should be well gridded to supply sufficient current to all areas of the board. A strong ground layout is advised to offset noise problems. Remember if the ground plane moves up in voltage because of excessive charge dumping in a particular area, the supply will drift up correspondingly. Sensing low levels often becomes an intermittent problem when proper ground is not provided.

APPLICATION EXAMPLE 1

MINIMUM SYSTEM APPLICATION AS A TEMPERATURE SENSOR

Overview

Following is an application example that illustrates the use of the interrupt and SOD pins on the 8085A, software for a block search routine, and the procedure for using and reading the 8155 counter. It is a simple application showing the use of the small but powerful 3-chip MCS-85 system as a temperature sensor (SDK-85 board used). This example can be modified to be an accurate industrial temperature controller, for several locations if desired.

The basic operation behind this application is a monostable multivibrator having its timing pulse duration controlled by a thermistor. The counter in the 8155 converts this timing pulse to a decimal count that is software mapped into a temperature and displayed in degrees C in the address field of the display in the SDK-85 Kit. For the purpose of keeping the software relatively simple, many approximations were incorporated into the code.

Detailed Hardware

The basic SDK kit was used for the initial hardware. This Kit provides for everything necessary to develop and debug a program through the use of the SDK-85 monitor, keyboard and display board. The kit provides for 256 bytes of RAM resident in the 8155 and 2K bytes of ROM or EPROM where the SDK-85 monitor is placed. (See the Intel SDK-85 User's Manual for copy of monitor software code.)

Figure 20 is a schematic of the SDK-85 Kit with only one 8155 and 8355. There is no buffering in this system as all components are on the same board and far below the maximum component loading. A monostable multivibrator (74121) is also shown with a thermistor connected to RE/CE.

The SOD output pin from the 8085A is used for the purpose of starting the monostable multivibrator in generating its temperature controlled timing pulse. This pulse is created by the RC time constant provided for by the thermistor acting as a variable resistor and a .1μF capacitor to put the timing pulse in the desired timing range.

The inverted output of the monostable multivibrator (one shot) has been directly connected to the RST 6.5 pin on the 8085A. Since this pin is high level sensitive, it is necessary to disable interrupts in the program until after the pulse from the one shot goes low.

The hardware addressing in the configuration shown allows for several code spaces that could be used. The RST and TRAP interrupt lines on the 8085A also have hardware start addresses but many of these are altered by the SDK monitor. Table 7 should be useful in understanding the addresses used in the software that follows. Each memory/ I/O component in the basic SDK-85 system is enabled by a signal coming from the 8205 address decoder. Since no expansion chips are used, output enables 00 (8355 monitor ROM), 03 (8279 Keyboard) and 04 (8155 RAM) were the only ones needed. Additional memory and/or I/O could have been incorporated using other output enables from the 8205.

Memory/ I/O Device	Function	Output from 8205	code space
8155	RAM space	04	2000 - 20FF (20 - 20FF are reserved for monitor RAM locations)
8355	ROM space	00	0000 - 07FF
8279	Keyboard/display controller	03	1800 - 1FFF

stack pointer

Since the monitor uses locations 10C8 through 20FF, the stack pointer must be initialized to 20C8 or less.

	8085A jump address	Usage	monitor mapped address
trap	24H	T0 of 8155	0157
RST 5.5	2CH	8279 interrupt	028E
RST 6.5	34H	oneshot interrupt	20CE
RST 7.5	3CH	vector interrupt	

I/O ports address	Function
00	Monitor ROM Port A (8355)
01	Monitor ROM Port B (8355)
02	Monitor ROM Port A (8355) Data direction register
03	Monitor ROM Port B (8355) Data direction register
20	Basic command/status register
21	Basic RAM Port A
22	Basic RAM Port B
23	Basic RAM Port C
24	Basic RAM LOW order byte of timer count
25	Basic RAM HIGH order byte of timer count

Table 7. Addressing

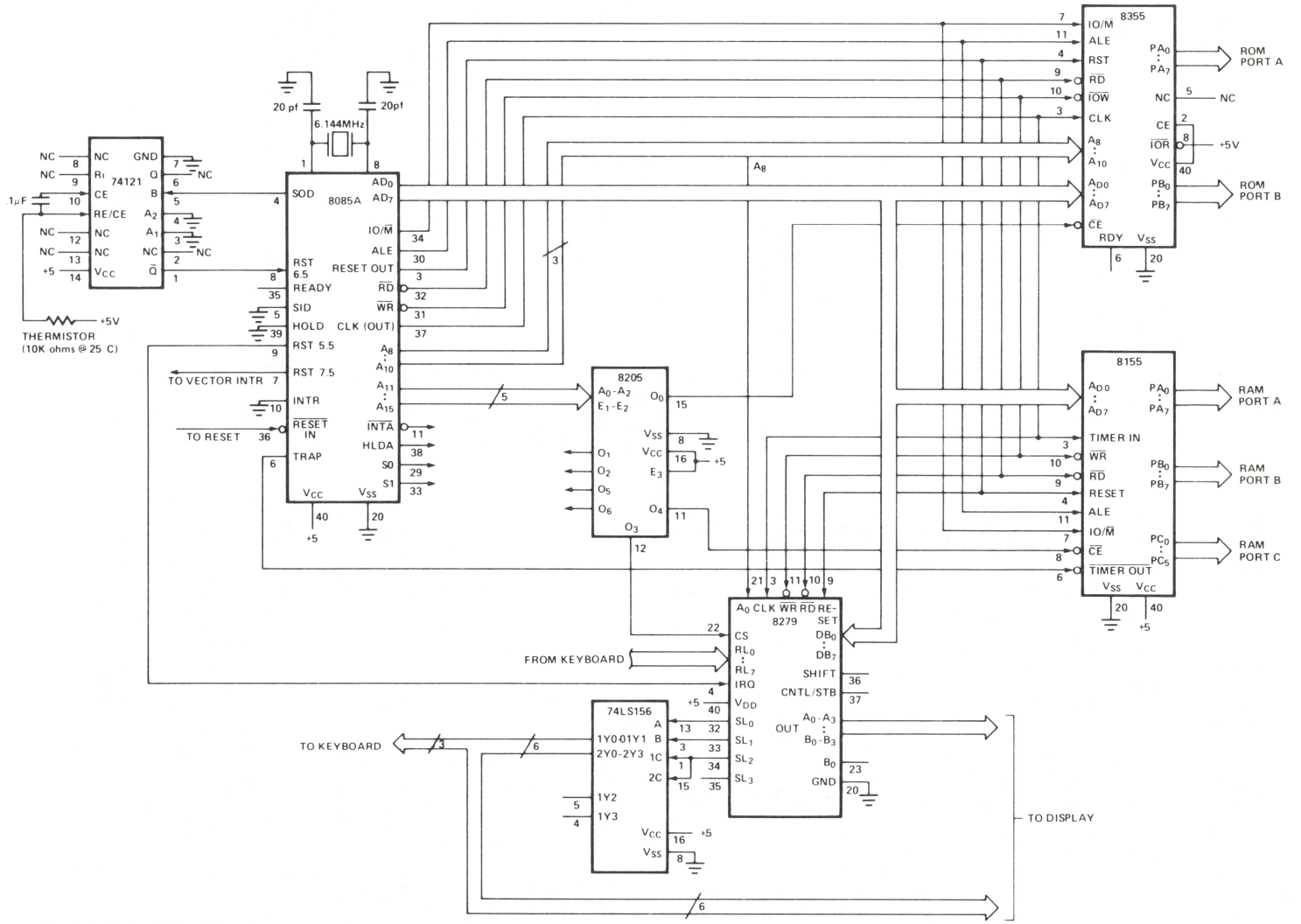


Figure 20. Detailed SDK-85 Kit with Temperature Sensor

Software

The software (at end of section) for this application illustrates several features of the 8085A, such as the programming of the SOD line, interrupts and 8155 counter. Additionally, an example of a block search routine is illustrated.

Figure 21 is a flow diagram of the program. It has been cross referenced with program lines to the actual software for the reader's convenience. Following through the flow diagram it is seen that the interrupts are disabled in the beginning as the one shot is outputting a high level on its Q output and interrupt pin 6.5 is high level sensitive. However, this high level will not be recognized until the level goes low and then high again. If the user would prefer a positive pulse interrupt the 8085A a dual one shot can be used with one triggering the other, or just a simple inverter. Starting and loading the counter is as described in the 8155 data sheet with the Port addresses being given in the previous Table (7). Code lines 18-23 represent placing the counter in the counter mode (single terminal count pulse at the end of count) and starting the count, having the count clocked by the 8085A clock out pin. Reading the counter is not as straight forward and will be approached shortly. Code lines 28-32 are representative of programming the SOD line to output a pulse. This pin is intended for serial I/O interfaces such as a teletype, but as seen in this application, it can also be used as a single I/O port.

After the pulse is presented to the one shot, the interrupts enabled, the processor idles (lines 36, 37; Halt could have just as easily been used) until interrupted. Through the design of this application it was known that the down counter would never reach terminal count, as it is only being used as a pulse to digital count converter.

To read in the count value it is best that the counter is first stopped. The least and most significant bytes of the count length register in the 8155 are read using the same port addresses as was used during loading the counter, as seen in code lines 42-47. If one looks at this value and knows how many pulses occurred, he would come to the conclusion that there is a gross discrepancy! The reason for this is that the counter in the 8155/6 was designed to make its square wave function generation easy and when used in the counter mode, it counts by two's. For this application (where length of time is mapped into a temperature) and other similar event timing applications it is imperative to have an intelligible count returned from the 8155.

The counter in the 8155 is essentially a count down by 2 counter. After it counts down by 2 the initial value loaded by the user, it reloads the initial count (initial count −1 if odd) and counts down by 2 again until terminal count is reached. When reading the counter, the least significant bit of the counter does not represent the least significant bit of the count, but which half of the countdown operation you are in. If this bit equals 1, the 8155/6 counter is counting down by 2 in the first half, and if it is zero you are in the second half of the operation. Because of this method of down counting there are two restrictions placed on its use:

1. The user can not use the initial value of 1 to detect only one pulse.
2. The user can not discern (through reading the counter) whether exactly one or two pulses on the timer input pin has occurred if he loaded in an initial odd count (does not apply to even). After three pulses the user can determine exactly how many pulses occurred. Note that this restriction only applies to reading the counter, the $\overline{TO}$ pin pulses correctly after the correct number of pulses regardless of what is read from the counter.

The first pulse to the 8155/6 counter (high level sensitive) loads the count length register, which says that the counter is not readable until a pulse occurs. If the user tries to read before a pulse is provided he will read a previous or old value. Now what is done with the value read?

Good question. An adjustment routine to convert this value read to an actual count can be summarized as follows:

1. Read in 16 bit count length register.
2. Reset the upper two bits (mode bits).
3. Reset carry and rotate right all 16 bits through carry.
4. If carry is set add 1/2 of full original count (1/2 (full count −1) if full count is odd).

In the software for this application is a general purpose routine to do this; lines 179-199. To call this routine it is assumed that the lower order byte of the counter is in register C, higher order byte in register B and full original count is in HL. Contents of H, L, B and C are destroyed returning actual count in BC register pair. To obtain the number of pulses that occurred, subtract this number from full original count and add 1.

Converting this remaining count to an actual temperature can be done by various methods but it was chosen to do a software map through the use of a block search routine. Table 8 presents approximations of what the remaining count should be for each temperature. To keep the software simple it was only necessary to compare the most significant byte to a list to find the appropriate temperature. This search routine is set up to find a "less than" match, incrementing the HL register as a pointer when a compare is made. The code for this search routine is in lines 118-144 and is optimized to be a fast 8 byte block search. This search routine can be made to search for a match by replacing all return on carry with return on zero. The performance of this subroutine is as follows:

$$\text{Byte time} = (11 + (166/8)\,N)\,CC/N = (11/N + 20.8)\,CC$$

where: CC = microseconds per clock cycle
N = total number of bytes searched
Byte time = time per byte searched

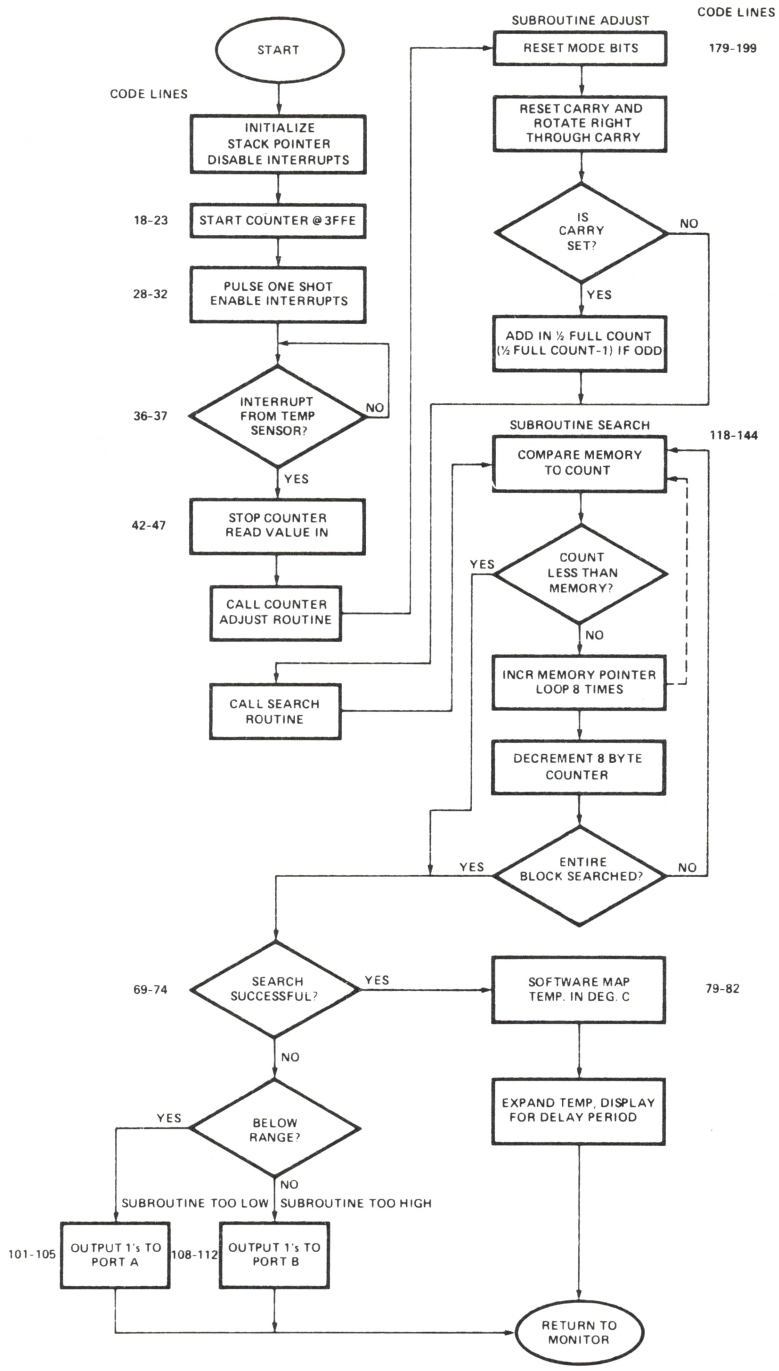


Figure 21. Temperature Sensor Flow Diagram

DEG. C	THERMISTOR OHMS	(.7) (.1μ) (R_T) APPROX. TIME (ms)	START WITH 3FFE$_H$ APPROX. COUNT LEFT (HEX)
20	12,490	.874	3585
21	11,940	.836	35FA
22	11,420	.799	366A
23	10,920	.764	36D5
24	10,450	.732	373A
25	10,000	.7	3772
26	9,573	.670	37D0
27	9,167	.642	384D
28	8,777	.614	38A1
29	8,407	.588	38F1
30	8,057	.564	393C
31	7,723	.541	3984
32	7,403	.518	39C8
33	7,097	.497	3A0A
34	6,807	.476	3A48
35	6,530	.457	3A84
36	6,267	.439	3ABC
37	6,017	.421	3AF2
38	5,747	.402	3B2C
39	5,547	.388	3B57
40	5,327	.373	3B86
41	5,117	.358	3BB3

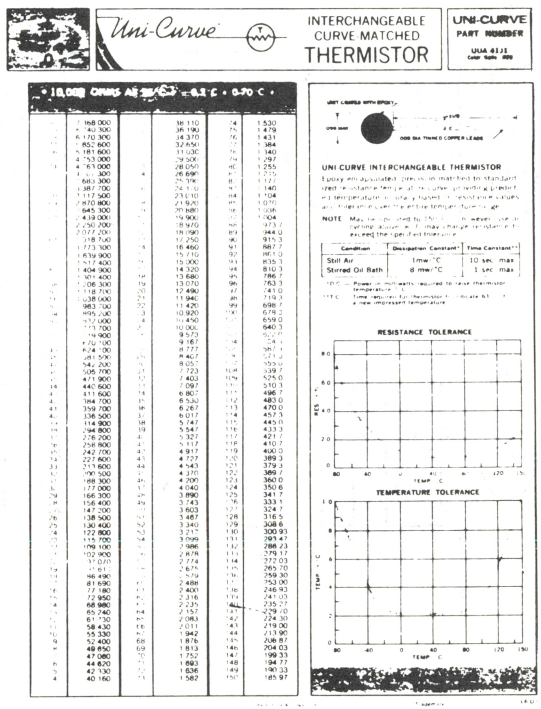
8085A Cycle Time = 326 ns

Oneshot Approx. Time =

L_{N2} (CEXT) (REXT)

$\approx$ (.7) (.1μ) $R_{THERMISTOR}$

Table 8. Thermistor Resistance Mapping



For an example with N = 256, CC = .32 μsec at 3.125 MHz; Byte time = 6.7 μsec. A match search routine with minimum memory usage is given below:

```
Search   Cmp M          compare byte
           RZ           return if match
         INX H          else increment pointer
         DCR C          has the entire
         JNZ search     block been searched?
         STC            If so set no match flag
         RET            and return.
```

In this application, a user may want to have several temperature ranges which can be swapped in and out with a block move subroutine. Similar code can be developed for this as shown below for a 4 byte move group:

```
BLKMV    LXI H, 000H    clear HL
         DAD SP         move SP to HL
         SHLD SAVESP    save sP
         MOV H, B       move Block move
         MOV L, C       Source address
         SPHL           To SP
         XCHG           Move Block move
                        address to HL
Loop     POP B          fetch four bytes from
         POP D          source store 1st byte
         MOV M, C       at destination
         INX H
         MOV M, B       2nd
         INX H
         MOV M, E       3rd
         INX H
         MOV M, D       4th
         INX H
         DCR A          check for end of
         JNZ Loop       Block move
         LHLD SAVESP    return old
         SPHL           SP
         RET            return
```

Once the count less than match is found in the application the HL register has 10 added to it which points it at the corresponding temperature (lines 79-82). This temperature is then displayed in the address field of the SDK 85 display using user available monitor routines. If the temperature is out of range the code detects it (lines 69-74) and outputs 1's on Port A or Port B if the temperature was too low or too high respectively (lines 101-105 "too low" and lines 108-112 "too high").

APPLICATION EXAMPLE 2

CRT INTERFACE

Most microprocessor systems require some sort of serial communications. This may be selected for reasons of economy (to reduce the number of interconnections required in a distributed system), or it may be necessary in order to communicate with such common peripherals as CRT's or teletypewriters.

These peripherals all use a standard convention for transmitting serial ASCII code. Each data byte is transmitted as a series of 10 or 11 bits. The uniform time per bit corresponds to the data transmission rate. For example, if the transmission rate is to be 2400 baud (2400 bits per second), each bit time must be 1/2400 bps = 416.7 μsec/bit. The standard 10-bit sequence consists of a logically zero "Start" bit, 8 data bits (least significant bit first), and one or more stop bits (logic 1). An 11-bit sequence with two stop bits is used for 110 baud TTY's. The logic one level continues until the start bit of the next byte to ensure that each 10-bit sequence is initiated with a one-to-zero transition. The 8 bits transferred might be raw binary data or alphanumeric characters using the standard ASCII code. In this case, the most significant bit – the last data bit transmitted – will depend on the parity convention being used. This sequence is illustrated for the ASCII "space" character in Figure 22.

The algorithm for receiving serial code involves sampling the incoming data at the middle of each bit time. The eight sampled values are shifted into a serial byte corresponding to the data originally transmitted. The one-to-zero transition at the beginning of each byte makes it possible to synchronize the sampling points relative to the start of each data sequence.

Hardware Interface

In general, any serial communications system will require both hardware and software interfaces. Since the SOD line can drive only one TTL load, additional current and voltage buffering is required to be compatible with the RS-232C interface standard used by most peripherals. A schematic for achieving this buffering is shown in Figure 23. The MC1488 and MC1489 circuits interface positive logic TTL signals with the RS-232 high voltage inverted logic levels.

Software Package

The software needed to drive the CRT interface is divided into three parts. All three use software timing and delay loops, with fixed and variable parameters. In conjunction, they are able to identify incoming signals at any rate from below 110 to over 9600 baud and respond at the same rate.

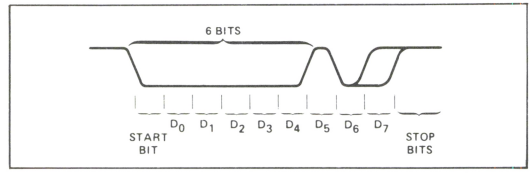


Figure 22. ASCII Space Character

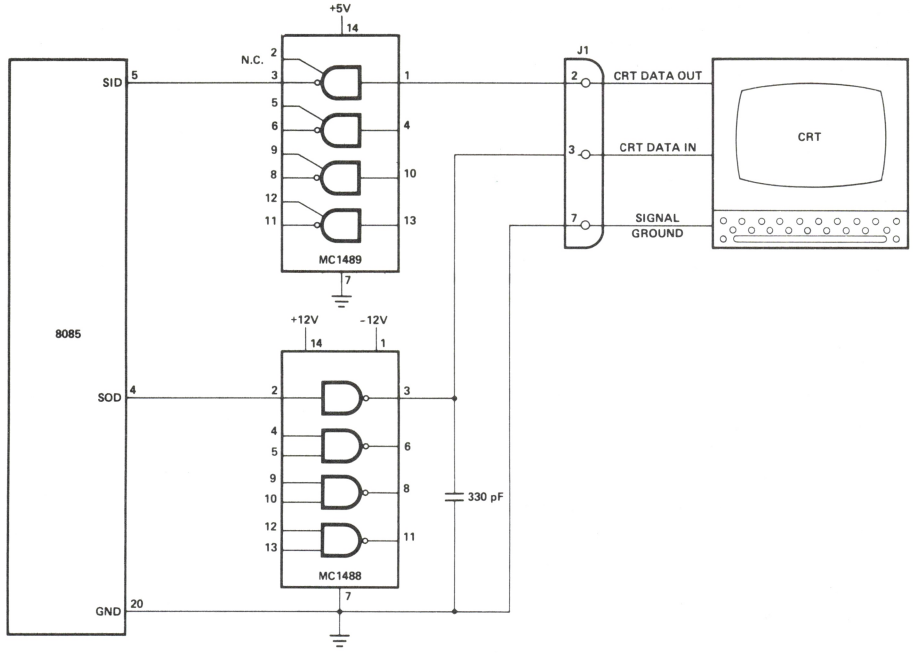


Figure 23. RS-232C Interface Schematic

Upon power-up or reset, or when the console device baud rate is changed, the baud rate identification subroutine (BRID) is called. This routine waits until an ASCII space character (20H) is received from the console. (Any other character will result in a case of mistaken identification.) When a space character is received, two time parameters are computed which correspond to the bit time and one-half the bit time of the baud rate being used. These are stored as variables BITTIME and HALFBIT. To output a character to the console, the character code is placed in register C, and the subroutine COUT is called. This routine uses BITTIME as a parameter for the software delay loop which determines the baud rate. To accept a character from the keyboard, CIN is called. CIN returns after the next key is typed, with the corresponding character code in register C. CIN uses both parameters BITTIME and HALFBIT.

Since COUT and CIN use time parameters computed by BRID, they will function at a rate the same as that of the initial space character input. Because of the nature of the software, the rate does not depend on the CPU clock frequency. This results in additional flexibility in the following respects:

1. The software does not need to be modified if the 8085 crystal frequency is changed or Wait states are added.
2. Since the time base is no longer critical, the quartz crystal could be replaced by a less expensive RC network, provided the frequency does not drift by more than a few percent during a session. Additional drift can be accommodated by periodically recalling the BRID routine.
3. Communication is possible at non-standard baud rates which relaxes the constraints on system peripherals.

It should be noted, though, that slowing down the CPU clock will decrease its throughput proportionately. In addition, it will degrade the maximum resolution of the delay loops, with the result that the highest baud rates may no longer be achievable.

A more detailed analysis of the CRT interface routines will be presented in the order of increasing complexity: COUT, CIN, and BRID. Since SID and

SOD are ideal for many applications which involve critical I/O timing, the timing techniques used here may be of interest to software designers. Accordingly, the mathematical derivation of the timing parameters is included in this analysis, as well as a justification for the BRID algorithm. The algebra involved might be a bit too tedious for designers unconcerned with generating software delays. If so, they (and other bored readers) have the freedom of choice to skip over the sections they find objectionable.

OUTPUT ROUTINE

It would seem natural to write data in the standard format in three stages: output a zero start bit, then the 8 data bits (using a loop sequence), then the stop bits. Each stage would incorporate its own appropriate delay and output sections, leading to unnecessary duplication. Instead, the code below executes the same main loop 11 times. Its bit manipulation routine inherently results in the correct data sequence being formed. It accomplishes this by using the carry and C register as a 9-bit pseudo-circular shift register. Initially CY=0. The algorithm outputs CY, waits one bit time, sets CY=1, and then rotates the pseudo-register right one bit. This repeats for 11 cycles. On the tenth and all subsequent loops, the output bit will be a logical one, since that bit had been set nine loops earlier while in the CY (see Figure 24).

When COUT is called the registers to be used must be preserved and interrupts disabled so the timing loop will not be disrupted. Clear the CY in preparation for outputting the start bit, and set the loop counter for 11 bits (if 110 baud will never be used, the counter could be set to 10):

```
COUT:   PUSH    B
        PUSH    H
        DI
        XRA     A
        MVI     B,11
```

Output of the contents of the CY:

```
C01:    MVI     A,80H       (7)
        RRR                 (4)
        SIM                 (4)
```

The numbers in brackets indicate how many machine cycles are required for each instruction. They will be referred to in the timing analysis section.

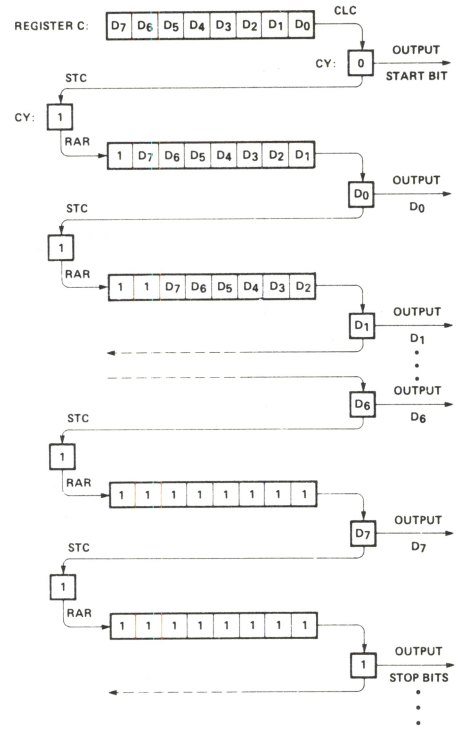


Figure 24. Data Serialization Algorithm

Get stuck in a loop for the appropriate time (don't worry for now how "BITTIME" is determined):

```
        LHLD    BITTIME     (16)
C02:    DCR     L           (5)
        JNZ     C02         (10)
        DCR     H           (5)
        JNZ     C02         (10)
```

Rotate the contents of register C right into the CY, while moving a one into the left end. Continue until all bits have been transmitted:

```
        STC                 (4)
        MOV     A,C         (5)
        RAR                 (4)
        MOV     C,A         (5)
        DCR     B           (5)
        JNZ     C01         (10)
```

Restore processor status and return:

```
        POP     H
        POP     B
        EI
        RET
```

INPUT ROUTINE

The console input routine uses the opposite procedure; instead of moving a bit from register C to the CY, then to A_7, then to SOD, CIN loads a bit from SID into A_7, then moves it to CY, then into register C.

First, set up the CPU as before:

```
CIN:    PUSH    H
        DI
        MVI     B,9
```

When a start bit transition arrives, the first sampling should not be taken until the middle of the first data bit, one and one-half bit times after the transition. Await the start bit transition, then set up the delay parameter for one-half bit time:

```
CI1:    RIM             ⟨4⟩
        ORA     A       ⟨4⟩
        JM      CI1     ⟨7⟩
        LHLD    HALFBIT ⟨16⟩
```

Loop for one-half bit time before starting to sample data:

```
CI2:    DCR     L       ⟨D⟩
        JNZ     CI2     ⟨D⟩
        DCR     H       ⟨D⟩
        JNZ     CI2     ⟨D⟩
```

Wait until the middle of the next bit before sampling SID, then move the data bit into CY:

```
CI3:    LHLD    BITTIME ⟨16⟩
CI4:    DCR     L       ⟨D⟩
        JNZ     CI4     ⟨D⟩
        DCR     H       ⟨D⟩
        JNZ     CI4     ⟨D⟩
        RIM             ⟨4⟩
        RAL             ⟨4⟩
```

Decrement the bit counter. If this is the ninth cycle, the 8 data bits are in register C, so quit (the first stop bit will already have been received, and be in CY):

```
        DCR     B       ⟨4⟩
        JZ      CI5     ⟨7⟩
```

Otherwise, continue. Rotate the data bit right into register C, and repeat the cycle:

```
        MOV     A,C     ⟨4⟩
        RAR             ⟨4⟩
        MOV     C,A     ⟨4⟩
        NOP             ⟨4⟩
        JMP     CI3     ⟨10⟩
```

(A NOP is needed to make the COUT and CIN loops exactly equal in number of machine cycles, so that each can use the same delay parameter.) Restore status and return.

```
CI5:    POP     H
        EI
        RET
```

TIMING ANALYSIS

COUT and CIN now need to be provided with parameters for BITTIME and HALFBIT. It can be seen from the above code that each routine uses 61 + D machine cycles per input or output bit, where D is the number of cycles spent in either four line delay segment. If ⟨H⟩ and ⟨L⟩ are the contents of the H and L registers going into this section of code, then:

$$D = 22 + (\langle L\rangle - 1) \times 14 + (\langle H\rangle - 1) \times [(255 \times 14) + 25] \quad (1)$$

If $\langle H\rangle' \equiv \langle H\rangle - 1$, $\langle L\rangle' \equiv \langle L\rangle - 1$, and

$$\langle HL\rangle' \equiv 256\,\langle H\rangle' + \langle L\rangle' \quad (2)$$

then

$$D = 22 + 14\,\langle L\rangle' + 3595\,\langle H\rangle' \quad (3)$$

This can be approximated by:

$$D = 22 + 14\,\langle HL\rangle' \quad (4)$$

This approximation is exact for $\langle H\rangle' = 0$; otherwise, it is accurate to within 0.3%. Thus each loop of COUT or CIN uses a total of:

$$C = 61 + D = 83 + 14\,\langle HL\rangle' \text{ machine cycles} \quad (5)$$

Each machine cycle uses two crystal cycles in the 8085, so the resulting data rate is:

$$B = \frac{\text{cycle frequency}}{C}$$

$$= \frac{(\text{crystal frequency}) \div 2}{83 + 14\,\langle HL\rangle'} \quad (6)$$

For a typical calculation, see the example below.

EXAMPLE

To produce 2400 baud with the standard 6.144 MHz crystal:

$$2400 = \frac{(6.144 \times 10^6) \div 2}{83 + 14\langle HL\rangle'}$$

$$14\langle HL\rangle' = \left(\frac{6.144 \times 10^6 \div 2}{2400}\right) - 83$$

$$\langle HL\rangle' = \left[\left(\frac{6.144 \times 10^6 \div 2}{2400}\right) - 83\right] \div 14 = 85.5 \cong 86$$

$$\langle HL\rangle' = 86_{10} = 0056H$$

$$\langle HL\rangle = 0157H = BITTIME$$

To determine the true data rate this parameter will produce, substitute into equation (6):

$$\text{Date Rate} = \frac{6.144 \times 10^6 \div 2}{83 + 14(86)}$$

$$= 2387 \text{ baud, which is 0.54\% slow.}$$

For 9600 baud, the same calculations will yield $\langle HL\rangle' = 17$, which is actually 0.3% slow; a sizzling 19200 baud or 38400 baud could each be generated to within 5% if $\langle HL\rangle' = 6$ or 0! Table 9 presents the parameters for several standard baud rates.

Notice that the resolution of the delay algorithm – the difference between bit times resulting from parameters which differ by one – is 14 machine cycles. As a result, the true bit delay produced can always manage to be within ±2.3 μsec of the delay desired. This guarantees that at rates up to 9600 baud, where each bit time is at least 104 μsec wide, some value of BITTIME can be found which will be accurate to within 2.2%.

BAUD RATE IDENTIFICATION ROUTINE

The function of BRID is to compute the appropriate parameters BITTIME and HALFBIT. It accomplishes this by observing the data pattern received when the space bar is pressed on the console device. Since a space character has the ASCII code 20H = 00100000B, the pattern represented back in Figure 4 is transmitted. Notice that the initial zero level is 6 bits wide. Suppose it could be determined that this corresponds to M machine cycles. Then one bit would correspond to (M÷6) machine cycles. The reason for dividing down a space several bits long is so that any distortion caused by the signal rise and fall times, or any lack of precision in detecting the two transitions, will be reduced by a factor of six. Since the bit period of COUT and CIN is $83 + 14\langle HL\rangle'$, BRID must generate a value $\langle HL\rangle'$ such that:

$$M \div 6 = 83 + 14\langle HL\rangle' \quad (7)$$

$$\langle HL\rangle' = \frac{(M \div 6) - 83}{14} \quad (8)$$

$$\langle HL\rangle' = \frac{M}{84} - 6 \text{ (approximately)} \quad (9)$$

This value can be determined by setting register pair HL to –6, then incrementing it once every 84 machine cycles during the period that the incom-

Table 9

DELAY PARAMETERS FOR STANDARD BAND RATES USING 6.144 MHz CRYSTAL

TARGET BAUD RATE	$\langle HL\rangle'_{10}$ (See Text)	$\langle HL\rangle'_{16}$ (See Text)	$\langle HL\rangle$ or BITTIME (See Text)	HALFBIT	ACTUAL BAUD RATE PRODUCED	% ERROR
110	1989	07C5	08C6	04E3	109.99	-0.006
150	1457	05B1	06B2	03D9	149.99	-0.005
300	726	02D6	03D7	026C	299.80	-0.068
600	360	0168	0269	01A5	599.65	-0.059
1200	177	00B1	01B2	0159	1199.5	-0.039
2400	86	0056	0157	012C	2386.9	-0.547
4800	40	0028	0129	0115	4777.6	-0.469
9600	17	0011	0112	0109	9570.1	-0.312
19200	6	0006	0107	0104	18395.2	-4.37

ing signal is zero. BITTIME is then obtained by individually incrementing registers H and L. To obtain HALFBIT, divide the value of ⟨HL⟩′ determined above by two before incrementing each register.

In order to implement this algorithm, set HL to −6, verify that the incoming signal is a logic one, then wait for the start bit transition.

```
BRID:   MVI     A,00H
        SIM
        LXI     H,-6H
BRI1:   RIM
        ORA     A
        JP      BRI1
BRI2:   RIM
        ORA     A
        JM      BRI2
```

Increment register pair HL, then delay so that each cycle will require 84 machine cycles:

```
BRI3:   INX     H           ⟨6⟩
        MVI     E,04H       ⟨7⟩
BRI4:   DCR     E           ⟨53⟩
        JNZ     BRI4        ⟨??⟩
```

Check if SID is still low. If so, repeat:

```
        RIM                 ⟨4⟩
        ORA     A           ⟨4⟩
        JP      BRI3        ⟨10⟩
```

Otherwise continue. Store HL temporarily for the HALFBIT calculation. Obtain and store BITTIME:

```
        PUSH    H
        INR     H
        INR     L
        SHLD    BITTIME
```

Restore HL, calculate HALFBIT, and return:

```
        POP     H
        ORA     A
        MOV     A,H
        RAR
        MOV     H,A
        MOV     A,L
        RAR
        MOV     L,A
        INR     H
        INR     L
        SHLD    HALFBIT
        RET
```

The assembled listings for these subroutines, along with a simple test program, is presented in the CRT and Cassette Code.

APPLICATION EXAMPLE 3

CASSETTE RECORDER INTERFACE

There are many situations where data has to be transmitted through a non-ideal medium. To give three typical examples, a system with electrically isolated elements might require that signals be AC coupled, communications through an audio network (such as telephone or radio) are greatly bandwidth limited, and some applications (such as a distributed network in an industrial environment) must tolerate random electrical noise. Attempting to record data on a cheap cassette recorder (the one used for this note cost $17.00) will reveal all of these shortcomings, plus one: The tape speed fluctuates significantly and varies as the batteries run down, hence the data rate is inconsistent.

The recording scheme used here makes very few demands on the transmission medium. It makes no attempt to transmit DC voltage levels. Instead, data is transmitted by a series of variable length tone bursts. The dominant frequency of the tone used can be selected to be within the passband of the particular medium. Data is transmitted with each bit composed of a tone burst followed by a pause. The first third of a bit period is always a tone burst, the middle third is either a tone burst continuous with the first or a pause corresponding to, respectively, a one or zero, and the final third is always a pause, as shown in Figure 25. Thus, data is distinguished by the burst/pause ratio.

Hardware Design

These tone bursts are obtained from the 8085 SOD line, using analog signal conditioning to eliminate the DC component of the waveform. (This low frequency component is due to the single-ended nature of the SOD line: it's deviations from ground are all positive, which unbalances the capacitive input stage of the recorder.) A suggested interface circuit is shown in Figure 26, using one LM324 quad op amp and a few standard value discrete components which should be available in even a digital design laboratory. On playback, analog circuitry is again used to detect the presence of a tone burst. In Figure 26, A2 buffers the incoming signal, and A3 inverts it. The peaks of these two signals are transmitted through D1 or D2 and are filtered by an RC network. Comparator A4 then squares up the output and produces the logic signal read by the SID pin. Since the op amps are powered by the single 5-volt supply, a 2.0-volt reference level is obtained from a resistive voltage divider. The waveforms present at several points in the circuit are shown in Figure 27.

Software

The algorithm for reading a data bit off the tape is simple and straightforward: If the tone burst is longer than the pause, the bit is a one. Otherwise, it is a zero. Since only the time ratio is considered, any variation in tape speed will not affect the data determination.

VOLUME CONTROL

A question that arises with any audio cassette interface is how to set the volume control. (Recording level is usually determined internally.) When the playback level is correct, the logic signal output from A4 will have either a one-third or two-thirds duty cycle. This can be readily observed with an oscilloscope. In the field, an old-fashioned mechanical-type voltmeter could be connected to the A4 output, and the volume adjusted until the meter needle hovered somewhere between 1/3 and 2/3 the high level output voltage. With random data, the reading would be about 2 volts. There will be a fairly wide range of acceptable volume settings. (Since the quivering meter needle is being used here for inertial signal averaging, a digital voltmeter would not be very helpful in this application.)

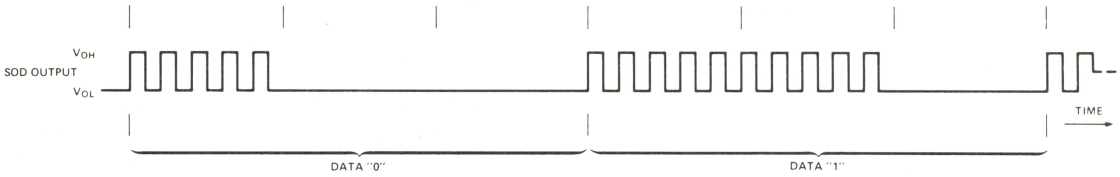


Figure 25. Tape Interface Data Recording Scheme

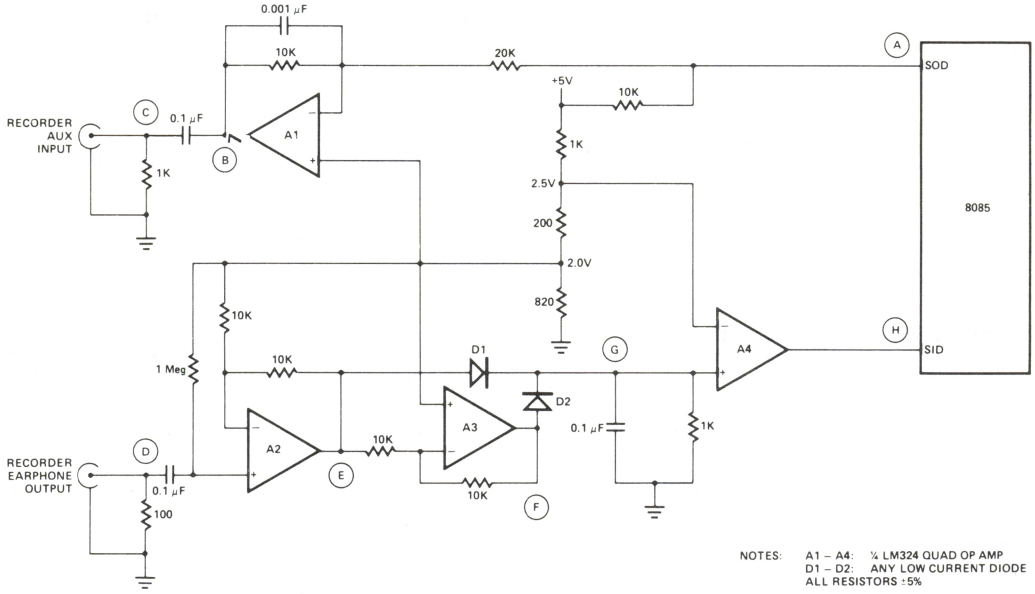


Figure 26. One Chip Magnetic Tape Interface Schematic

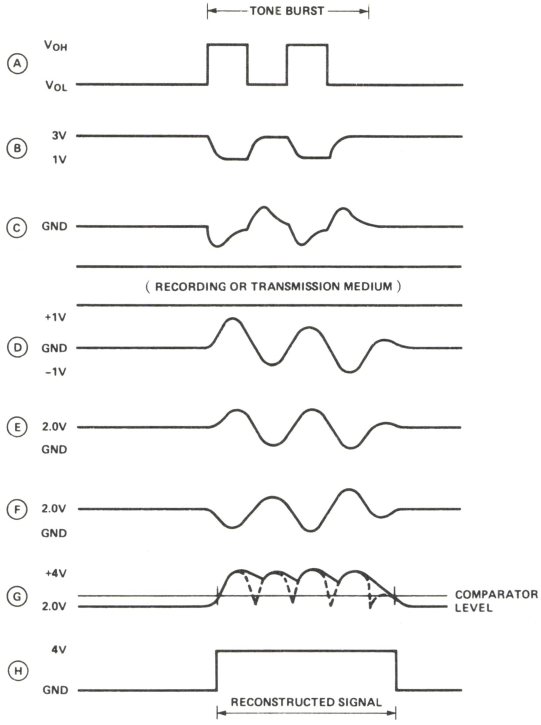


Figure 27. Analog Signal Waveforms

After the CRT software analysis, the tape routines are almost trivial. TAPEO is a subroutine for outputting the contents of register C to a cassette recorder. TAPEIN reads 8 bits into register C.

OUTPUT ROUTINE

TAPEO calls a subroutine named BURST three times for each bit. If A_6 (the SOD enable bit) is set when BURST is called, a square-wave tone burst will be transmitted. If A_6 is not set, BURST simply delays for exactly the same amount of time before returning. The three calls are used to, respectively, output the initial burst, output the data burst/space, and create the space at the end of each bit. Nine bits will be output: the eight data bits (LSB first) followed by a zero bit. The start of the initial burst of the trailing zero is needed to mark the end of the final space of the preceding data bit.

Start each bit by outputting a tone burst:

```
TAPEO:  MVI     B,9
TO1:    MVI     A,0C0H
        CALL    BURST
```

Rotate register C through CY:

```
        MOV     A,C
        RAR
        MOV     C,A
```

Move CY to the SOD enable bit position, A_6. Simultaneously set A_7 to one, and clear all other bits. Output a tone burst or space, depending on the previous contents of CY:

```
        MVI     A,01H
        RAR
        RAR
        CALL    BURST
```

Clear the accumulator, and output a space:

```
        XRA     A
        CALL    BURST
```

Keep cycling until the full 9-bit sequence is finished:

```
        DCR     B
        JNZ     TO1
        RET
```

The BURST subroutine executes the SIM instruction CYCNO times, at intervals of 29 + 14 ⟨HALFCYC⟩ machine cycles. In between each SIM, bit A_7 is complemented. CYCNO should be an even number. If A_6 is set upon calling BURST a square-wave will be created. Otherwise, the same code sequence is followed but SOD does not change – thus a space results.

```
BURST:  MVI     D,CYCNO         ⟨7⟩
BU1     SIM                     ⟨4⟩
        MVI     E,HALFCYC       ⟨7⟩
BU2:    DCR     E               ⟨4⟩
        JNZ     BU2             ⟨7/10⟩
        XRI     80H             ⟨7⟩
        DCR     D               ⟨4⟩
        JNZ     BU1             ⟨7/10⟩
        RET                     ⟨10⟩
```

INPUT ROUTINE

TAPEIN uses a subroutine called BITIN to move the data at the SID pin into the CY. The maximum rate at which SID is read is limited by a delay loop in BITIN.

Initialize the bit counter and the register D, which will keep track of the tone burst time. If a tone

burst is being received when TAPEIN is called, wait until the burst is over:

```
TAPEIN: MVI     B,8
        MVI     D,00H
TI1:    CALL    BITIN
        JC      TI1
        CALL    BITIN
        JC      TI1
```

(Throughout this subroutine, a level transition is recognized only after it has been read once initially and then verified on the next reading. This provides some degree of software noise immunity.) Now await the start of the next burst:

```
TI2     CALL    BITIN
        JNC     TI2
        CALL    BITIN
        JNC     TI2
```

The next burst has now arrived. Keep reading the SID pin, decrementing register D (thus making it more negative), each cycle until the pause is detected:

```
TI3     DCR     D
        CALL    BITIN
        JC      TI2
        CALL    BITIN
        JC      TI2
```

Now continue reading the SID pin, incrementing the D register (back towards zero), each cycle until the next burst is received:

```
TI4     INR     D
        CALL    BITIN
        JNC     TI4
        CALL    BITIN
        JNC     TI4
```

Now, if the burst lasted longer than the space, D was not incremented all the way back to zero; it is still negative. If the space was longer, D was incremented up through zero; it is now positive. In other words, the sign bit of D will now correspond to the data bit that would lead to each of these results. Move the sign bit into the CY, then rotate it into register C:

```
        MOV     A,D
        RAL
        MOV     A,C
        RAR
        MOV     C,A
        MVI     D,00H
```

Continue until the last bit has been received:

```
        DCR     B
        JNZ     TI3
        RET
```

(Notice that the first half of this subroutine is incorporated in the second half. In fact, the assembled listing included in the Appendix makes use of this fact to eliminate 24 bytes of duplicated code.)

BITIN waits a short time in order to regulate the sampling rate, then reads SID and moves the data bit into the CY:

```
BITIN:  MVI     E,CKRATE        <7>
BI1:    DCR     E               <4>
        JNZ     BI1             <7/10>
        PIM                     <4>
        RAL                     <4>
        RET                     <10>
```

The tone burst frequency and duration, and the TAPEIN sampling rate are determined by HALFCYC, CYCNO, and CKRATE. Tables 10 and 11 give typical values.

Table 10

EXAMPLE COMBINATIONS OF HALFCYC AND CYCNO.
ALL VALUES IN DECIMAL

APPROXIMATE TONE FREQUENCY	CORRESPONDING HALFCYC VALUE	RESULTING DATA RATE			
		8 4	20 10	100 50	CYCNO CYC/BURST
500 Hz	217	42	17	3.3	bps
1 kHz	108	83	33	6.6	bps
2 kHz	53	166	66	13	bps
5 kHz	20	414	166	33	bps
10 kHz	9	826	330	66	bps

Table 11

MAXIMUM SAMPLING RATES FOR VARIOUS VALUES OF CKRATE

CKRATE VALUE	SAMPLING RATE (INCLUDING CALL & RET)
1	17.6 μsec
20	104 μsec
80	378 μsec
250	1.14 msec

The CRT and Cassette Code also includes a simple block record routine utilizing TAPEO. Before calling BLKRCD, HL must be set to the start of the desired block, and the recorder turned on manually. Successive bytes will be recorded until the end of that page, i.e., until L is incremented to zero. The playback routine requires presetting HL to the target address and turning on the recorder before PLAYBK is called. These routines incorporate a long tone burst before each data block to allow a recorder with Automatic Gain Control to stabilize before the data starts.

ADDITIONAL COMMENTS

The two design examples given so far were built up using an SDK-85 System Design Kit. Both hardware interfaces were wire-wrapped on the ample breadboarding area provided on the board. The connections between SID and SOD and the on-board TTY interface were broken, so as not to affect the 8085 I/O electrical characteristics.

The CRT interface was tested with a Beehive Mini-Bee II Terminal in the full duplex mode at each of its 14 possible transmission rates, from 110 to 9600 baud. It was also checked out at 19200 baud using a Beehive B-100 terminal. In addition, the software was exercised using an SBC 80/20 system as a variable baud rate character generator and receiver.

An additional advantage to having software selectable communications rates is that it would be possible to communicate with several system periperals, each at its own preferred rate, without having to duplicate hardware. For example, the addition of a single 7408 AND gate and an output port (such as on the 8155) would make it possible to use the same two RS-232 circuits to interface with up to seven I/O devices (see Figure 28). Three of the MC1488 drivers have Enable inputs which can be controlled by the output port. One AND gate can be used to buffer the SOD line and drive the MC1488 Data inputs. The rest of the 7408 can be configured as a four input AND gate. This would act as an inverted logic OR gate to reduce the four MC1489 receiver outputs to a single line, which could be read by the SID. This assumes that only one input device (CRT, PTR) at a time will be used (which is usually the case in a non-time shared, interactive application), and that the unused devices are transmitting a logic one level (which should also be the case).

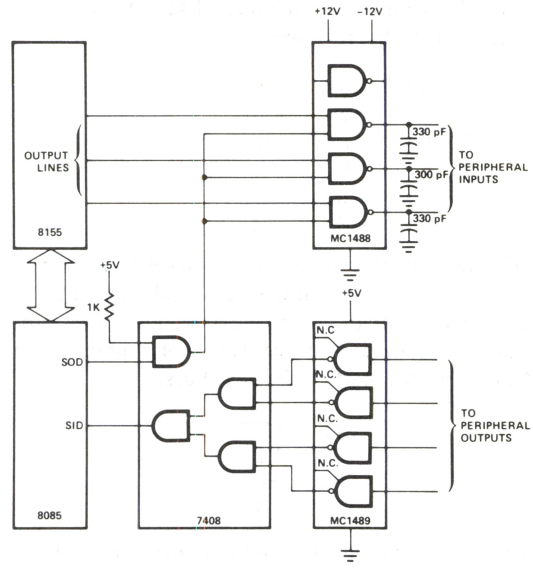


Figure 28. Interfacing 8085 to Multiple Peripherals

The software needed to support additional peripherals would be simple and straightforward. A routine intended to dump a section of memory to a paper tape punch, for example, would first have to store BITTIME and HALFBIT somewhere (perhaps on stack), load the variables with new parameters corresponding to the paper tape punch rate, and then write a bit pattern to the output port which would disable the console driver and enable the punch (and perhaps a typewriter). After the dump was over, the original time parameters and driver status would be restored.

As explained before, the BRID routine computed rate parameters based on the fact that an ASCII "space" character resulted in a zero level 6 bits long. Conceivably, some obscure peripherals might produce a transient between successive zero bits. (This might be the case, for example, if the signal was produced by mechanical rather than electronic means.) If so, the BRID algorithm used here probably would not work reliably. Once the two time parameters were identified, though, COUT and CIN could still be used. An alternate algorithm for baud rate identification would require a table in ROM (note the fifth and final R/S-I/O-M/D permutation). This table would contain a list of delay parameters corresponding to the standard transmis-

sion rates, as computed for the selected crystal frequency. Initialization would require the operator to hit a specific key several times (usually the "U" key, which generates a pattern of alternating ones and zeros). The identification routine would attempt to "read" this pattern at each baud rate, in turn, until finding the rate at which the read was successful.

The cassette recorder used to develop the tape interface was a Lloyd's push-button model which cost $17 in 1972. Empirical testing has indicated that for this application, the quality of the cassette recorder is less critical than the quality of the tape itself. In other words, some 33¢ cassettes were not very reliable, even when used with more expensive recorders.

When using a cassette at the beginning of a side, allow the tape to run for about 10 seconds until the leader has passed before starting to write data. Otherwise, data will be lost to the leader.

Depending on the recorder quality, the tone burst frequency and duration can be optimized for higher data rates by modifying HALFCYC and CYCNO. If so, CKRATE should also be reduced, so that between about 10 and 80 data samplings are made during a single (one-third width) tone burst. At greatly increased frequencies, some of the components in the analog interface might also be modified.

The two simple routines for recording and playing back blocks of data were intended to illustrate one way of using TAPEIN and TAPEO, and therefore do not contain any provisions for error detection or correction. Depending on the nature of a particular application, these routines could be augmented with parity bit or checksum comparison, or an error correcting code technique.

Funny things happen when recording and playing back a page of RAM which includes the subroutine stack. Eventually, PLAYBK will start writing over the data at the top of the stack, destroying the subroutine traceback sequence. The next RET instruction will then cause a jump to a place where you'd rather not be.

The printout reproduced in the CRT Code includes the assembled listings for the CRT and magnetic tape interfaces discussed in this application note. The object code produced was programmed into an 8755 EPROM, which was installed in the expansion PROM socket of the SDK-85 board. Some very minor differences exist between this listing and the code segments presented earlier, which were written for maximum clarity.

Temperature Sensor Code

```
ASM80 :F1:TEST.SRC MOD85


ISIS-II 8080/8085 MACRO ASSEMBLER, V2.0        MODULE   PAGE   1


 LOC  OBJ         SEQ         SOURCE STATEMENT

                    1 ;
                    2 ;
 026C               3 HXDSP   EQU     026CH           ;EXPAND HEX TO DISPLAY, SDK MONITOR ROUTINE
 02B7               4 OUTPUT  EQU     02B7H           ;OUTPUT TO DISPLAY, SDK MONITOR ROUTINE
 05F1               5 DELAY   EQU     05F1H           ;DELAY DISPLAY, SDK MONITOR ROUTINE
                    6 ;
 2000               7 ORG     2000H
                    8 ;
                    9 ;
                   10 ;
                   11 ;
 2000 31C820       12         LXI     SP,20C8H        ;INITIALIZE STACKPOINTER
 2003 F3           13         DI                      ;DISABLE INTERRUPTS
                   14 ;
                   15 ;  INITIALIZE COUNTER IN 8155 FOR COUNTDOWN MODE.  LOAD COUNTER
                   16 ;  WITH HIGHEST VALUE (3FFF).
                   17 ;
 2004 3EBF         18         MVI     A,0BFH
 2006 D325         19         OUT     25H             ;ADDRESS FOR TOP HALF OF COUNTER
 2008 3EFF         20         MVI     A,0FFH
 200A D324         21         OUT     24H             ;   "       "  LOWER HALF OF COUNTER
 200C 3EC0         22         MVI     A,0C0H
 200E D320         23         OUT     20H             ;COUNT DOWN MODE START
                   24 ;
                   25 ;  PULSE THE ONE SHOT WITH A POSITIVE GOING PULSE ON THE SOD
                   26 ;  OUTPUT PIN OF THE 8085.
                   27 ;
 2010 3EC8         28         MVI     A,0C8H
 2012 30           29         SIM                     ;OUTPUT A HIGH ON SOD LINE
 2013 3E48         30         MVI     A,48H
 2015 30           31         SIM                     ;OUTPUT A LOW ON SOD LINE
 2016 FB           32         EI                      ;ENABLE INTERRUPTS(AFTER PULSE)
                   33 ;
                   34 ;  IDLE UNTIL ONESHOT INTERRUPTS THE RST 6.5 PIN ON THE 8085.
                   35 ;
 2017 00           36 NPO    NOP
 2018 C31720       37         JMP     NPO             ;IDLE UNTIL INTERRUPT
                   38 ;
                   39 ;  AFTER INTERRUPT, STOP COUNTER AND READ IN FINAL COUNT FROM
                   40 ;  8155.  STORE IN REGISTER PAIR BC.
                   41 ;
 201B 3E40         42 CNTU   MVI     A,40H
 201D D320         43         OUT     20H             ;STOP COUNTER
 201F DB24         44         IN      24H
 2021 4F           45         MOV     C,A             ;STORE LOWER ORDER BYTE IN C
 2022 DB25         46         IN      25H
 2024 47           47         MOV     B,A             ;STORE HIGHER ORDER BYTE IN B
 2025 263F         48         MVI     H,3FH           ;LOAD HL WITH FULL START COUNT
 2027 2EFF         49         MVI     L,0FFH
                   50 ;
                   51 ;  ADJUST THE COUNT VALUE IN REGISTER BC TO REPRESENT ACTUAL
                   52 ;  COUNT  (SEE TEXT FOR EXPLANATION)
```

Temperature Sensor Code (Cont'd)

```
ISIS-II 8080/8085 MACRO ASSEMBLER, V2.0        MODULE  PAGE   2


 LOC  OBJ        SEQ        SOURCE STATEMENT

                  53 ;
 2029 CD6820      54         CALL    ADJUST          ;CONVERTS 8155 COUNT TO ACTUAL COUNT
                  55 ;
                  56 ;  SETUP INITIALIZATION FOR SEARCH ROUTINE.  ROUTINE LOOKS FOR TEMPERATURE
                  57 ;  RANGE OF COUNT (SEE TEXT).  SEARCH ONLY FOR UPPER HALF TO SIMPLIFY CODE.
                  58 ;
 202C 2E80        59         MVI     L,80H           ;SET HL TO BEGINNING OF SEARCH
 202E 2620        60         MVI     H,20H           ;STRING IN MEMORY.
 2030 B0          61         ORA     B               ;CLEAR CARRY FOR ROUTINE.
 2031 78          62         MOV     A,B             ;PLACE B INTO ACCUMULATOR
 2032 0E01        63         MVI     C,1H            ;SET TIMES THROUGH SEARCH
 2034 CD9220      64         CALL    SEARCH          ;LOOKS FOR TEMP RANGE COUNT IS IN
                  65 ;
                  66 ;  CHECK IF SEARCH WAS SUCCESSFUL.  IF NOT THEN OUTSIDE ACCEPTABLE
                  67 ;  RANGE.
                  68 ;
 2037 3E80        69         MVI     A,80H           ;DID L FIND LESS THAN AT
 2039 AD          70         XRA     L               ;AT BEGINNING OF STRING?
 203A CAAF20      71         JZ      TLOW            ;TEMP BELOW ALLOWED LIMITS, SET PORT A
 203D 3E00        72         MVI     A,00H           ;DID C GET DECREMENTED?
 203F B9          73         CMP     C               ;IF SO,SEARCH DID NOT FIND
 2040 CAB820      74         JZ      THIGH           ;TEMP ABOVE LIMITS, SET PORT B
                  75 ;
                  76 ;  SOFTWARE MAP THE MATCH TO A TEMPERATURE IN DEGREES C BY ADDING
                  77 ;  10 TO SEARCH ADDRESS.  PLACE TEMPERATURE IN REGISTER E.
                  78 ;
 2043 3E0A        79         MVI     A,0AH           ;SHIFT HL BY 10 (SOFTWARE MAP)
 2045 85          80         ADD     L
 2046 6F          81         MOV     L,A
 2047 5E          82         MOV     E,M             ;READ IN TEMPERATURE
                  83 ;
                  84 ;  SET UP INITIALIZATION FOR DISPLAYING TEMPERATURE USING SDK
                  85 ;  MONITOR ROUTINES.  FIRST EXPAND DE REGISTER AND THEN DISPLAY
                  86 ;  FOR DELAY PERIOD.
                  87 ;
 2048 0600        88         MVI     B,00H           ;CLEAR DOT AT ADDRESS FIELD
 204A CD6C02      89         CALL    HXDSP           ;CALL EXPAND
 204D 3E00        90         MVI     A,00H
 204F CD8702      91         CALL    OUTPUT          ;OUTPUT TO SDK DISPLAY
 2052 11FF00      92         LXI     D,0FFH          ;SET DELAY PERIOD
 2055 CDF105      93         CALL    DELAY           ;DISPLAY FOR DELAY PERIOD
 2058 CF          94         RST     1               ;SOFTWARE RESTART
                  95 ;
                  96 ;  SUBROUTINES
                  97 ;
 20AF             98 ORG     20AFH
                  99 ;
                 100 ;
 20AF 3E03       101 TLOW    MVI     A,03H
 20B1 D320       102         OUT     20H
 20B3 3EFF       103         MVI     A,0FFH          ;SET PORT A AS 1'S
 20B5 D321       104         OUT     21H
 20B7 CF         105         RST     1
                 106 ;
                 107 ;
```

Temperature Sensor Code (Cont'd)

```
ISIS-II 8080/8085 MACRO ASSEMBLER, V2.0        MODULE   PAGE   3


 LOC  OBJ         SEQ         SOURCE STATEMENT

 2088 3E03         108 THIGH:  MVI     A,03H
 208A D320         109         OUT     20H
 208C 3EFF         110         MVI     A,0FFH          ;SET PORT B AS 1'S
 208E D322         111         OUT     22H
 2090 CF           112         RST     1
                   113 ;
                   114 ;
 2092              115 ORG     2092H
                   116 ;
                   117 ;
 2092 BE           118 SEARCH: CMP     M
 2093 D8           119         RC
 2094 23           120         INX     H               ;ELSE INCREMENT POINTER
 2095 BE           121         CMP     M               ;COMPARE 2ND BYTE
 2096 D8           122         RC
 2097 23           123         INX     H
 2098 BE           124         CMP     M               ;COMPARE 3RD BYTE
 2099 D8           125         RC
 209A 23           126         INX     H
 209B BE           127         CMP     M               ;COMPARE 4TH BYTE
 209C D8           128         RC
 209D 23           129         INX     H
 209E BE           130         CMP     M               ;COMPARE 5TH BYTE
 209F D8           131         RC
 20A0 23           132         INX     H
 20A1 BE           133         CMP     M               ;COMPARE 6TH BYTE
 20A2 D8           134         RC
 20A3 23           135         INX     H
 20A4 BE           136         CMP     M               ;COMPARE 7TH BYTE
 20A5 D8           137         RC
 20A6 23           138         INX     H
 20A7 BE           139         CMP     M               ;COMPARE 8TH BYTE
 20A8 D8           140         RC
 20A9 23           141         INX     H
 20AA 0D           142         DCR     C               ;HAS ENTIRE BLOCK BEEN
 20AB C29220       143         JNZ     SEARCH          ;SEARCHED? IF SO SET NO
 20AE C9           144         RET                     ;LESS THAN AND RETURN
                   145 ;
                   146 ;  RESTART 6.5 JUMP ADDRESS
                   147 ;
 20CE              148 ORG     20CEH
                   149 ;
                   150 ;
 20CE C31B20       151         JMP     CNTU
                   152 ;
                   153 ;
                   154 ;
                   155 ;
                   156 ;
                   157 ;
                   158 ;  SEARCH COMPARE DATA STRING (SEE TEXT)
                   159 ;
                   160 ;
 2080              161 ORG     2080H
                   162 ;
```

Temperature Sensor Code (Cont'd)

```
ISIS-II 8080/8085 MACRO ASSEMBLER, V2.0        MODULE   PAGE    4


 LOC  OBJ         SEQ         SOURCE STATEMENT

                  163 ;
 2080 35          164         DB      35H,36H,37H,38H,39H,3AH,3BH,3CH
 2081 36
 2082 37
 2083 38
 2084 39
 2085 3A
 2086 3B
 2087 3C
                  165 ;
                  166 ;  SOFTWARE MAP TO TEMPERATURE
                  167 ;
 208B             168 ORG     208BH
                  169 ;
                  170 ;
 208B 21          171         DB      21H,23H,25H,28H,31H,35H,39H
 208C 23
 208D 25
 208E 28
 208F 31
 2090 35
 2091 39
                  172 ;
                  173 ;
 2060             174 ORG     2060H
                  175 ;
                  176 ;
                  177 ;  SUBROUTINE ADJUST FOR COUNT IN 8155
                  178 ;
 2060 78          179 ADJUST: MOV     A,B             ;LOAD ACCUMULATOR WITH UPPER HALF
 2061 E63F        180         ANI     3FH             ;RESET UPPER TWO BITS,CLEAR CARRY
 2063 1F          181         RAR                     ;ROTATE RIGHT THROUGH CARRY
 2064 47          182         MOV     B,A             ;STORE SHIFTED VALUE BACK IN B
 2065 79          183         MOV     A,C             ;LOAD ACCUMULATOR WITH LOWER HALF
 2066 1F          184         RAR                     ;ROTATE WITH CARRY RIGHT
 2067 4F          185         MOV     C,A             ;STORE SHIFTED VALUE IN C
 2068 D0          186         RNC                     ;1ST HALF OR SECOND? IF SECOND RETURN
 2069 3F          187         CMC                     ;CLEAR CARRY
 206A 7C          188         MOV     A,H             ;OBTAIN ONE HALF OF FULL COUNT
 206B 1F          189         RAR                     ;IF HL IS ODD THIS CONTAINS
 206C 67          190         MOV     H,A             ;ONE HALF(FULL COUNT-1), WHICH
 206D 7D          191         MOV     A,L             ;IS CORRECT
 206E 1F          192         RAR
 206F 6F          193         MOV     L,A
 2070 09          194         DAD     B               ;DOUBLE PRECISION ADD
 2071 44          195         MOV     B,H             ;RESTORE BC REGISTERS WITH COUNT
 2072 4D          196         MOV     C,L
 2073 C9          197         RET
                  198 ;
                  199 ;
                  200         END

PUBLIC SYMBOLS


EXTERNAL SYMBOLS


USER SYMBOLS


ISIS-II 8080/8085 MACRO ASSEMBLER, V2.0        MODULE   PAGE    5


ADJUST A 2060    CNTU   A 2018    DELAY  A 05F1    HXDSP  A 026C    NPO    A 2017    OUTPUT A 0287    SEARCH A 2092
THIGH  A 2068    TLOW   A 20AF

ASSEMBLY COMPLETE,  NO ERRORS
```

CRT and Cassette Code

```
ISIS-II 8080/8085 ASSEMBLER, V4.0      MODULE                    PAGE    1

  LOC  OBJ        SEQ        SOURCE STATEMENT

                    0 $   NOGEN TITLE('8085 SERIAL I/O NOTE APPENDIX')
```

CRT and Cassette Code (Cont'd)

```
ISIS-II 8080/8085 ASSEMBLER, V1.0      MODULE                          PAGE    2
8085 SERIAL I/O NOTE APPENDIX


LOC  OBJ         SEQ        SOURCE STATEMENT


                   1
                   2 ;       THE FOLLOWING PROGRAMS AND SUBROUTINES ARE DESCRIBED IN DETAIL
                   3 ;       IN INTEL CORPERATION'S APPLICATION NOTE AP-29, "USING THE 8085
                   4 ;       SERIAL I/O LINES".  THE FIRST SECTION IS A GENERAL PURPOSE CRT
                   5 ;       INTERFACE WITH AUTOMATIC BAUD RATE IDENTIFICATION; THE SECOND
                   6 ;       SECTION IS A MAGNETIC TAPE INTERFACE FOR STORING DATA ON CASSETTE
                   7 ;       TAPES.  THE CODE PRESENTED HERE IS ORIGINED AT LOCATION 800H,
                   8 ;       AND MIGHT BE PART OF AN EXPANSION PROM IN AN INTEL SDK-85
                   9 ;       SYSTEM DESIGN KIT.
                  10 ;
                  11
                  12
20C8              13 BITTIME EQU     20C8H   ;ADDRESS OF STORAGE FOR COMPUTED BIT DELAY
20CA              14 HALFBIT EQU     20CAH   ;ADDRESS OF STORAGE  FOR HALF BIT DELAY
000B              15 BITSO   EQU     11      ;DATA BITS PUT OUT (INCLUDING TWO STOP BITS)
0009              16 BITSI   EQU     9       ;DATA BITS TO BE RECIEVED (INCLUDING ONE STOP BIT)
                  17
0800              18         ORG     800H    ;STARTING ADDRESS OF SDK-85 EXPANSION PROM
                  19
                  20 ;CRTTST CRT INTERFACE TEST.  WHEN CALLED, AWAITS THE SPACE BAR BEING PRESSED ON
                  21 ;       THE SYSTEM CONSOLE, AND THEN RESPONDS WITH A DATA RATE VERIFICATION
                  22 ;       MESSAGE.  THERE AFTER, CHARACTERS TYPED ON THE KEYBOARD ARE ECHOED
                  23 ;       ON THE DISPLAY TUBE.  WHEN A BREAK KEY IS TYPED, THE ROUTINE IS
                  24 ;       RE-STARTED, ALLOWING A DIFFERENT BAUD RATE TO BE SELECTED ON THE CRT.
0800 31C020       25 CRTTST: LXI     SP,20C8H
0803 3EC0         26 CRT1:   MVI     A,0C0H  ;SOD MUST BE HIGH BETWEEN CHARACTERS
0805 30           27         SIM
0806 CD1A08       28         CALL    BRID    ;IDENTIFY DATA RATE USED BY TERMINAL
0809 CD4708       29         CALL    SIGNON  ;OUTPUT SIGNON MESSAGE AT RATE DETECTED
080C CD8A08       30 ECHO:   CALL    CIN     ;READ NEXT KEYSTROKE INTO REGISTER C
080F 79           31         MOV     A,C
0810 B7           32         ORA     A       ;CHECK IF CHARACTER WAS A <BREAK> (ASCII 00H)
0811 CA0308       33         JZ      CRT1    ;IF SO, RE-IDENTIFY DATA RATE
                  34                         ;THIS ALLOWS ANOTHER RATE TO BE SELECTED ON CRT
0814 CD6909       35         CALL    COUT    ;OTHERWISE COPY REGISTER C TO THE SCREEN
0817 C30C08       36         JMP     ECHO    ;CONTINUE INDEFINITELY (UNTIL BREAK)
                  37
                  38 ;BRID   BAUD RATE IDENTIFICATION SUBROUTINE
                  39 ;       EXPECTS A <CR> (ASCII 20H) TO BE RECIEVED FROM THE CONSOLE.
                  40 ;       THE LENGTH OF THE INITIAL ZERO LEVEL (SI% BITS WIDE) IS MEASURED
                  41 ;       IN ORDER TO DETERMINE THE DATA RATE FOR FUTURE COMMUNICATIONS.
081A 20           42 BRID:   RIM             ;VERIFY THAT THE "ONE" LEVEL HAS BEEN ESTABLISHED
081B B7           43         ORA     A       ;\ AS THE CRT IS POWERING UP
081C F21A08       44         JP      BRID
081F 20           45 BRI1:   RIM             ;MONITOR SID LINE STATUS
0820 B7           46         ORA     A
0821 FA1F08       47         JM      BRI1    ;LOOP UNTIL START BIT IS RECIEVED
0824 21FAFF       48         LXI     H,-6    ;BIAS COUNTER USED IN DETERMINING ZERO DURATION
0827 1E04         49 BRI3:   MVI     E,04H
0829 1D           50 BRI4:   DCR     E       ;52 MACHINE CYCLE DELAY LOOP
082A C22909       51         JNZ     BRI4
082D 23           52         INX     H       ;INCREMENT COUNTER EVERY 84 CYCLES WHILE SID IS LOW
082E 20           53         RIM
```

CRT and Cassette Code (Cont'd)

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ISIS-II 8080/8085 ASSEMBLER, V1.0       MODULE                          PAGE   3
8085 SERIAL I/O NOTE APPENDIX

 LOC  OBJ         SEQ         SOURCE STATEMENT

 082F B7           54         ORA     A
 0830 F22708       55         JP      BRIZ
                   56                         ;<HL> NOW CORRESPONDS TO INCOMING DATA RATE
 0833 E5           57         PUSH    H       ;SAVE COUNT FOR HALFBIT TIME COMPUTATION
 0834 24           58         INR     H       ;BITTIME IS DETERMINED BY INCREMENTING
 0835 2C           59         INR     L       ;\ H AND L INDIVIDUALLY
 0836 22C820       60         SHLD    BITTIME
 0839 E1           61         POP     H       ;RESTORE COUNT FOR HALFBIT DETERMINATION
 083A B7           62         ORA     A       ;CLEAR CARRY
 083B 7C           63         MOV     A,H     ;ROTATE RIGHT EXTENDED <HL>
 083C 1F           64         RAR             ;\ TO DIVIDE COUNT BY 2
 083D 67           65         MOV     H,A
 083E 7D           66         MOV     A,L
 083F 1F           67         RAR
 0840 6F           68         MOV     L,A
 0841 24           69         INR     H       ;PUT H AND L IN PROPER FORMAT FOR DELAY
 0842 2C           70         INR     L       ;\ SEGMENTS (INCREMENT EACH)
 0843 22CA20       71         SHLD    HALFBIT ;SAVE AS HALF-BIT TIME DELAY PARAMETER
 0846 C9           72         RET
                   73
                   74 ;SIGNON WRITES A SIGN-ON MESSAGE TO THE CRT AT WHAT SHOULD BE THE CORRECT RATE.
                   75 ;       IF THE MESSAGE IS UNINTELLIGIBLE.     WELL, SO IT GOES.
 0847 215508       76 SIGNON: LXI     H,STRNG ;LOAD START OF SIGN-ON MESSAGE
 084A 4E           77 S1      MOV     C,M     ;GET NEXT CHARACTER
 084B AF           78         XRA     A       ;CLEAR ACCUMULATOR
 084C B1           79         ORA     C       ;CHECK IF CHARACTER IS END OF STRING
 084D C8           80         RZ              ;RETURN IF SIGN-ON COMPLETE
 084E CD6908       81         CALL    COUT    ;ELSE OUTPUT CHARACTER TO CRT
 0851 23           82         INX     H       ;INDEX POINTER
 0852 C34A08       83         JMP     S1      ;ECHO NEXT CHARACTER
                   84
 0855 0D           85 STRNG:  DB      0DH,0AH ;<CR><LF>
 0856 0A
 0857 42415544     86         DB      'BAUD RATE CHECK'
 085B 20524154
 085F 45204348
 0863 45434B
 0866 0D           87         DB      0DH,0AH ;<CR><LF>
 0867 0A
 0868 00           88         DB      00H     ;END-OF-STRING ESCAPE CODE
                   89
                   90 ;COUT   CONSOLE OUTPUT SUBROUTINE
                   91 ;       WRITES THE CONTENTS OF THE C REGISTER TO THE CRT DISPLAY SCREEN
 0869 F3           92 COUT    DI
 086A C5           93         PUSH    B
 086B E5           94         PUSH    H
 086C 060B         95         MVI     B,BITS0 ;SET NUMBER OF BITS TO BE TRANSMITTED
 086E AF           96         XRA     A       ;CLEAR CARRY
 086F 3E80         97 CO1     MVI     A,80H   ;SET WHAT WILL BECOME SOD ENABLE BIT
 0871 1F           98         RAR             ;MOVE CARRY INTO SOD DATA BIT OF ACC
 0872 30           99         SIM             ;OUTPUT DATA BIT TO SOD
 0873 2AC820      100         LHLD    BITTIME
 0876 2D          101 CO2:    DCR     L       ;WAIT UNTIL APPROPRIATE TIME HAS PASSED
```

CRT and Cassette Code (Cont'd)

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ISIS-II 8080/8085 ASSEMBLER, V1.0      MODULE                          PAGE    6
8085 SERIAL I/O NOTE APPENDIX

  LOC  OBJ        SEQ        SOURCE STATEMENT

  08FF C9          208        RET
                   209
                   210 ;PLAYBK         WAITS FOR THE LONG LEADER BURST TO ARRIVE, THEN CONTINUES
                   211 ;               READING BYTES FROM THE RECORDER AND STORING THEM
                   212 ;               IN MEMORY STARTING AT LOCATION <HL>.
                   213 ;       CONTINUES UNTIL THE END OF THE CURRENT PAGE (<L>=0FFH) IS REACHED.
  0900 0EFA        214 PLAYBK: MVI     C,LDRCHK        ;<LDRCHK> SUCCESSIVE HIGHS MUST BE READ
  0902 CD3D09      215 PB1:    CALL    BITIN           ;\ TO VERIFY THAT THE LEADER IS PRESENT
  0905 D20009      216         JNC     PLAYBK          ; \ AND ELECTRONICS HAS STABILIZED
  0908 0D          217         DCR     C
  0909 C20209      218         JNZ     PB1
  090C CD1509      219 PB2:    CALL    TAPEIN  ;GET DATA BYTE FROM RECORDER
  090F 71          220         MOV     M,C     ;STORE IN MEMORY
  0910 2C          221         INR     L       ;INCREMENT POINTER
  0911 C20C09      222         JNZ     PB2     ;REPEAT FOR REST OF CURRENT PAGE
  0914 C9          223         RET
                   224
                   225 ;TAPEIN CASSETTE TAPE INPUT SUBROUTINE.  READS ONE BYTE OF DATA
                   226 ;       FROM THE RECORDER INTERFACE AND RETURNS WITH THE BYTE IN REGISTER C.
  0915 0609        227 TAPEIN: MVI     B,9     ;READ EIGHT DATA BITS
  0917 1600        228 TI1:    MVI     D,00H   ;CLEAR UP/DOWN COUNTER
  0919 15          229 TI2:    DCR     D       ;DECREMENT COUNTER EACH TIME ONE LEVEL IS READ
  091A CD3D09      230         CALL    BITIN
  091D DA1909      231         JC      TI2     ;REPEAT IF STILL AT ONE LEVEL
  0920 CD3D09      232         CALL    BITIN
  0923 DA1909      233         JC      TI2
  0926 14          234 TI3:    INR     D       ;INCREMENT COUNTER EACH TIME ZERO IS READ
  0927 CD3D09      235         CALL    BITIN
  092A D22609      236         JNC     TI3     ;REPEAT EACH TIME ZERO IS READ
  092D CD3D09      237         CALL    BITIN
  0930 D22609      238         JNC     TI3
  0933 7A          239         MOV     A,D
  0934 17          240         RAL             ;MOVE COUNTER MOST SIGNIFICANT BIT INTO CARRY
  0935 79          241         MOV     A,C
  0936 1F          242         RAR             ;MOVE DATA BIT RECIEVED (CY) INTO BYTE REGISTER
  0937 4F          243         MOV     C,A
  0938 05          244         DCR     B
  0939 C21709      245         JNZ     TI1     ;REPEAT UNTIL FULL BYTE ASSEMBLED
  093C C9          246         RET
                   247
  093D 1E16        248 BITIN:  MVI     E,CKRATE
  093F 1D          249 BI1:    DCR     E
  0940 C23F09      250         JNZ     BI1     ;LIMIT INPUT SAMPLING RATE
  0943 20          251         RIM             ;SAMPLE SID LINE
  0944 17          252         RAL             ;MOVE DATA INTO CY BIT
  0945 C9          252         RET
                   254
                   255         END


PUBLIC SYMBOLS
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CRT and Cassette Code (Cont'd)

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ISIS-II 8080/8085 ASSEMBLER, V1.0       MODULE                          PAGE   7
8085 SERIAL I/O NOTE APPENDIX


EXTERNAL SYMBOLS


USER SYMBOLS
BI1     A 093F    BITIN   A 093D    BITSI   A 0009    BITSO   A 000B    BITTIM A 20C8    BLKRCD A 08B9    BR1     A 08BD
BR2     A 08C9    BRI1    A 091F    BRI3    A 0827    BRI4    A 0829    BRID    A 081A    BU1     A 08F2    BU2     A 08F5
BURST   A 08F0    CI1     A 088E    CI2     A 0896    CI3     A 089E    CI4     A 08A1    CI5     A 08B6    CIN     A 088A
CKRATE  A 0016    CO1     A 086F    CO2     A 0875    COUT    A 0869    CRT1    A 0803    CRTTST A 0800    CYCNO   A 0010
ECHO    A 080C    HALFBI  A 20CA    HALFCY  A 001E    LOADCHK A 00FA    LEADER  A 00FA    PB1     A 0902    PB2     A 090C
PLAYBK  A 0900    S1      A 084A    SIGNON  A 0847    STRNG   A 0855    TAPEIN  A 0915    TAPEO   A 08D1    TI1     A 0917
TI2     A 0919    TI2     A 0926    TO1     A 08D5

ASSEMBLY COMPLETE.  NO ERROR(S)
```

CRT and Cassette Code (Cont'd)

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ISIS-II ASSEMBLER SYMBOL CROSS REFERENCE V1.0                    PAGE   1

PI1      249#   250
BITIN    215    230    222    235    227    248#
BITSI     16#   120
BITSO     15#    95
BITTIM    12#    60    100    129
BLKRCD   163#
BR1      165#   167
BR2      170#   172
BRI1      45#    47
BRI2      49#    55
BRI4      50#    51
BRID      28     42#    44
BU1      201#   207
BU2      203#   204
BURST    165    169    184    191    193    200#
CI1      121#   123
CI2      125#   126    128
CI3      129#   142
CI4      130#   131    133
CI5      137    143#
CIN       30    118#
CKRATE   155#   248
CO1       97#   110
CO2      101#   102    104
COUT      25     91     92#
CRT1      26#    33
CRTTST    25#
CYCNO    153#   200
ECHO      30#    36
HALFBI    14#    71    124
HALFCY   154#   202
LOPCHK   157#   214
LEADER   156#   162
PB1      215#   218
PB2      219#   222
PLAYBK   214#   216
S1        77#    83
SIGNON    29     76#
STRNG     76     95#
TAPEIN   219    227#
TAPEO    171    179#
TI1      228#   245
TI2      229#   231    233
TI3      224#   236    238
TO1      192#   195

CROSS REFERENCE COMPLETE
```

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